THE IMPACT OF URBANIZATION ON BIODIVERSITY IN THE ASHEVILLE-BREVARD COMBINED STATISTICAL AREA

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Applied Research Paper
Georgia Institute of Technology
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April 2019

ACKNOWLEDGEMENTS

I would not have finished this paper without the guidance and support from Dr. Brian Stone. Thank you for helping me troubleshoot how to make my results understandable.

A special thanks to Dr. Ross Meentemeyer and Dr. Brian Pickard for responding to my requests for data and questions regarding their work on development projections in Western North Carolina.

To the Georgia Tech School of City and Regional Planning Class of 2019, thank you for all the time spent bouncing around paper topics and ideas as well as positive encouragement as we worked on our Applied Research papers together.

Finally, I want to thank my family and friends for listening to me talk about this project repeatedly. A special thanks to my sister, Sara, for sending me pictures she took in Brevard and Hendersonville to use in my final report.

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INTRODUCTION

Humans are part of an exclusive grouping of animals known as ecosystem engineers because they change and create livable environments to suit their needs. In addition to building shelters and cultivating the land, humans have created expansive groupings of buildings in pursuit of greater economic and civic activities. We call these groupings cities. In terms of absolute size, the combined land mass of cities covers a relatively small portion of the Earth; however, urban environments have far reaching effects on habitats around the globe.

Urban areas impact the biodiversity of the natural environments within and around them. The biodiversity of regions provides several ecosystem services to humans such as food production, water filtration, soil formation, pollination, and resilience to natural disasters. Without these services, humans would need to engineer solutions to continue our survival. Due to the intricate connection of humans to the natural environment, it is important to act in ways to preserve and encourage biodiversity.

The Asheville-Brevard Combined Statistical Area (CSA) presents an opportunity to plan for the prevention of biodiversity degradation (Figure 1). The CSA has three characteristics that make it an ideal

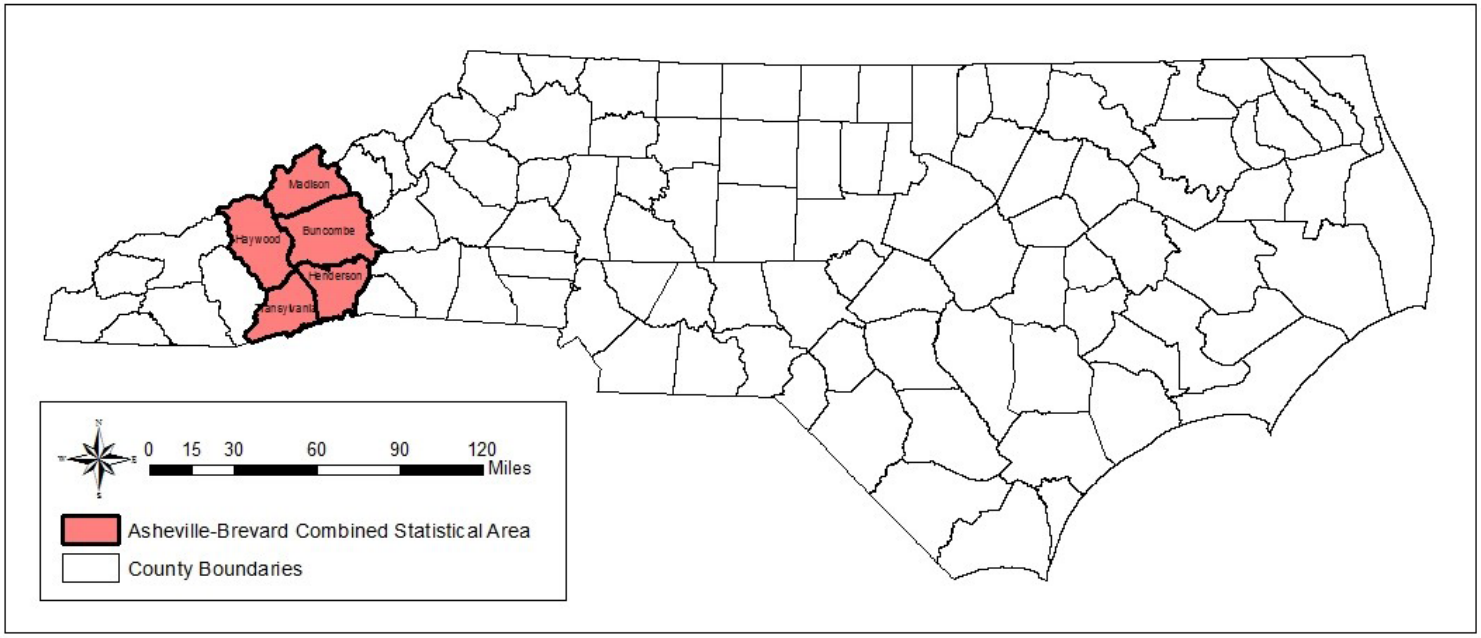

Figure 1. Asheville-Brevard Combined Statistical Area

study area. First, the ecoregion is biologically diverse with thousands of species of plants and insects, as well as hundreds of species of vertebrates. Second, Western North Carolina experienced more than a 570 percent increase in urban land since the 1970s and this trend is projected to continue (Vogler et al. 2010, iii). Third, there are a variety of protected areas within the five counties, which limit where development can occur. In addition, the mountains are an aesthetic resource that should be protected.

This study attempts to answer the following question: Based on land use projections, where will urbanization have the greatest impact on biodiversity in the Asheville-Brevard Combined Statistical Area? It is hypothesized that urbanization will have the greatest impact on biodiversity in locations closer to the protected areas of the region (i.e., Great Smoky Mountains National Park, Nantahala National Forest, Pisgah National Forest, DuPont State Forest, Bracken Preserve) since these areas will have higher biodiversity due to their adjacency to more complete habitats.

This report is structured as follows. First, a review of the literature is presented regarding the importance of biodiversity, the impact of urbanization on biodiversity, best practices in biological conservation, and the current methodologies for studying the future impact of development on biodiversity. The literature review concludes with a discussion of study's theory and contribution to the literature. Second, the methodology is outlined. Third, the report presents the data and analysis. Fourth, a discussion of the results leads to recommendations for how the Asheville-Brevard CSA should address urban development in areas whose development is projected to have a large impact on biodiversity.

LITERATURE REVIEW

This chapter makes the case for why humans should protect biodiversity. It also explores the impacts of urbanization on biodiversity along with best practices for biological conservation. In addition, a discussion of current methodologies for mapping the impact of urbanization on biodiversity is presented. Finally, the chapter concludes with a description of this study's theory and expected contribution to the literature by choosing to conduct a relatively large-scale analysis.

Importance of Protecting Biodiversity

Over the course of millennia, species located in the same area interact and evolve together to create a balanced ecosystem. When new species are introduced or humans change the ecosystem, imbalances can occur which hurt the life within the ecosystem as well as the ecosystem's ability to perform crucial functions that humans need to survive. The Western North Carolina Vitality Index defines biodiversity as

Biodiversity is important to protect because it helps maintain the delicate balance of the ecosystem. A high amount of biodiversity, such that exists in Western North Carolina (WNC), can help the ecosystem be more resilient to threats and shocks to the system (Folke 1998). While some argue that biodiversity should be protected for the sake of the species themselves, this argument fails to consider that ecosystems change and the Earth has experienced several phases of mass extinctions (Schilthuizen 2018).

> *the variety and abundance of all life forms in a given place – plants, animals, and other living organisms such as fungi, lichens, and mosses. Biological diversity also describes the processes, functions, and structures that sustain that variety and allow it to adapt to changing circumstances. Moreover, it encompasses the complexity of gene pools, species, communities, and ecosystems at spatial scales from local to region to global (UNC Asheville's NEMAC 2016, 70).*

Just like ants and beavers, humans are ecosystem builders and we depend on our built ecosystems and the surrounding ecosystems to provide services to sustain our lifestyles. Ecosystem services are benefits that the natural environment provides, which humans would need to provide if the environment failed to supply them (Elmquist et al. 2013a). For example, some services ecosystems offer are detoxification and decomposition of waste, purification of air and water, generation and renewal of soil and soil fertility, and pollination and pest control (Colding 2013; Folke 1998). However, it is difficult to determine which species contribute to these services or the supply chain for the species that do contribute (Salzman and Thompson 2003). The ecosystem provides a more cost-effective alternative to humans using manual labor or building technologies to achieve the same results.

The amount of ecosystem services that humans use makes up their ecological footprint. Humans currently use one fourth of the food that the world's plants produce and half of the freshwater run-off (Schilthuisen 2018, 6). As hubs for people, goods, and economic activities, cities use large tracts of ecosystems (primarily outside

of their boundaries and around the world) for consumption and waste assimilation purposes (Elmquist et al. 2013b; Folke 1998). This indirect effect on ecosystems is a byproduct of urbanization (Güneralp et al. 2013). As a city grows, the surrounding land cannot fully support the needs of its inhabitants. While it is important to understand indirect impacts on biodiversity, it is outside the scope of this study, which focuses on land adjacent to urban and peri-urban areas in WNC.

The WNC mountains, forests, and watersheds provide specific ecosystem services to their surrounding inhabitants including fine hardwood timber, carbon pools, soil formation from crystalline rocks, erosion control and landslide prevention, drinking water, and aesthetic benefits (UNC Asheville's NEMAC 2016). WNC forests are estimated to store 240 million tons of carbon, primarily in live trees and soil (69). The Southern Appalachian Ecoregion, where the Asheville-Brevard CSA is located, "contains an estimated 80 species of amphibians and reptiles, 175 species of terrestrial birds, 65 species of mammals, 2,250 species of vascular plants, and…as many as 25,000 species of invertebrates" (UNC Asheville's NEMAC 2016, 70). WNC contains 10 river basins, which drain 11,459 square miles (54). Three river basins lie within the study area with the French Broad having the most coverage. According to the Forests to Faucets dataset (2011), the importance of forests to the existence of surface drinking water in the study area ranges from 30 to 100 percent. Overall, Western North Carolina provides a variety of ecosystem services to its inhabitants and those in other urban areas. However, rapid population growth may be affecting the region's ability to provide these services.

Effect of Urbanization on Biodiversity

As the so-called urban century progresses, few, if any, ecosystems around the world have remained unaffected by human actions. Planning for environmental health cannot be addressed without considering the actions and spatial distribution of human populations (Handel et al. 2013). Both the processes of urbanization and the indirect byproducts of urban growth affect the biodiversity of the ecosystems surrounding cities.

One of the most visible effects of urbanization is rapid urban growth incorporating swaths of land into the urban matrix. This transforms the original ecosystem into an urban ecosystem with little resemblance to the land's previous incarnation. Worldwide, urban land is growing at rates at least twice as fast as urban populations (Seto, Güneralp, and Hutyra 2012, 16083). In addition, studies suggest that more than half of the urban land cover by 2030 will be built in the first three decades of the 21st century (16085). While the first two decades have almost passed, there is still time to affect growth policies, especially in countries with robust planning institutions, such as the United States.

While most of the urban growth is projected to occur in developing countries, areas within the U.S. are also experiencing rapid changes. For example, urban land in WNC is projected to increase at a rate of 0.4 acres per person by 2030 (Vogler et al 2010). Within the Asheville-Brevard CSA, the development threat to forests that are important to surface water, ranges from 0 to 70 percent (Forests to Faucets, 2011). In addition, habitat destruction threatens the overall health of the aquatic ecosystems within WNC. Development, point and nonpoint source pollution, hydrologic alteration, and

poor management of agriculture and forestlands all contribute to the ecosystem degradation (UNC Asheville's NEMAC 2016).

The encroachment of urban land on protected areas also represents a challenge from urbanization. Almost 60 percent of urban land in the United States is within 25km of protected areas, and almost 90 percent of the urban land is within 50km (Güneralp and Seto 2013, 5). On the one hand, this closeness allows city inhabitants to experience and learn from nature in ways they may not be able to if the protected land was farther away or did not exist. This could instill a sense of stewardship in visitors. On the other hand, urban land may negatively impact the biodiversity within the protected area. The effect of urbanization on protected areas depends on the effectiveness of land use, conservation, and urbanization policies as well as coordination between different agencies and governments (Güneralp et al. 2013).

Another issue with urbanization is the fragmentation of habitats. Fragmentation lowers the movement of species from place to place and decreases the gene pool species that are forced to live in smaller habitats. Larger patches are able to contain more native species than smaller patches (Müller et al. 2013). There are efforts to create corridors within urban environments; however, once urban infrastructure has been established, planners encounter difficulties with restoring corridors due to existing urban land uses along potential routes (Handel et al. 2013).

The urban environment also changes the quality of habitats that remain within the urban fabric. Soil quality, temperature and heat island effect, water stress, and pollution all affect gains and losses of species within a habitat (Handel et al. 2013; Müller et al. 2013). The physical and chemical changes of cities often make areas inhospitable to many native species (Handel et al. 2013). However, an unfavorable habitat for one species may be the perfect ecological niche for a different species.

The urban ecosystem is often teaming with non-native and invasive species. It is estimated that invasive species cause US$120 billion annually in environmental losses and damages in the U.S. (McPhearson et al. 2013, 364). As one travels from the rural edge of cities to the urban core, the amount of native species declines, while the amount of non-native species increases to around 30-50 percent of the total species in the core (Müller et al. 2013). This influx of non-native species is the result of intentional and unintentional transport by humans into the urban area. In addition, the rise of commercial nurseries with unified products leads to homogenization of species and a suppression of local biodiversity (Müller et al. 2013).

Part of the reason for this homogenization of species in cities around the world is due to the unique ecosystem cities create that is much closer to each other than the surrounding land. Many native species cannot adapt to living in cities, therefore preservation and conservation of wilderness and rural land is important to preserve the vast majority of the world's species (Schilthuizen 2018). We do not yet know all of the species that will provide important services or will be better suited for urban environments as cities promote sustainable practices.

While the above arguments present the negative impacts of urbanization on biodiversity, some scholars argue that if increased biodiversity is the ultimate goal, urban environments help achieve

it. Cities create new habitats and the influx of non-native species does increase the total biodiversity of the city, sometimes with peaks in the urban core for plants and insects (Schilthuizen 2018; Müller et al. 2013). Cities are often located in parts of the world that already have high biodiversity since humans tend to choose locations with many opportunities for food and water in which to settle (Schilthuizen 2018). Schilthuizen (2018) also argues that urban environments are not ecosystem matrixes, but rather, are a multitude of habitat patches, which help enable high biodiversity. However, the biodiversity that cities currently promote does not have the capacity to provide all the ecosystem services needed by its inhabitants. It is important for planners, institutions, and governments to promote policies and strategies that manage ecosystems and sustain them for future generations.

Best Practices in Biological Conservation

The ultimate goal in biological conservation from an ecosystem services perspective is to maintain and build the current urban ecosystem services in an effort to prevent biodiversity losses. The Convention on Biological Diversity provides the following recommendations for cities:

1. Sustain ecosystem services for and within cities.
2. Conserve biodiversity within urban areas and promote sustainable design.
3. Influence decision-making to create livable spaces for humans, plants, and animals (Müller et al. 2013).

These guidelines adhere to an ecosystem management approach because they seek to maintain or restore "the composition, structure, and function of natural and modified ecosystems for the goal of long-term sustainability" (Meffe and Carroll 1997, 361). Some ways to achieve these recommendations are to focus on native species, treat all patches as opportunities, plant urban trees, and invest in green infrastructure (Colding 2013; Müller et al. 2013). In addition, cities should build visible ecosystem services into the urban environment to allow residents to play a more active role in the ecosystem management (Colding 2013).

These guiding principles are meant to apply to cities all around the globe; however, planners must remember to base these recommendations in the environmental and cultural context of each locale. Planting trees may not be necessary in a heavily forested area such as WNC, but both Asheville and Hendersonville have a Tree Commission/Board. These departments designate, monitor, and protect heritage trees, as well as oversee planting trees to provide erosion control on slopes and pollination activities ("City of Asheville Tree Commission" n.d.; "Tree Board" n.d.).

One of the oldest ways to protect biodiversity is to set aside ecologically valuable land for nature conservation and preservation. Preservation is the mechanism through which nature is protected from use, and conservation seeks the proper use of nature. While the National Park Service may have started in an effort to preserve land for future generations to enjoy, the parks also help preserve biodiversity.

The Endangered Species Act of 1973 also calls for protection of habitats through preservation. Officials can use listed species as a proxy for habitat degradation because they are often found in

areas within naturally high biodiversity. However, once a species is put on the endangered species list, the habitat is severely degraded past the point of restoration (Salzman and Thompson, 2003). Both conservation and preservation protect biodiversity and ecosystem services; however, preservation often ignores the needs of humans to transform ecosystems for use, such as timber for construction purposes (Meffe and Carroll, 1997).

Local governments in WNC still use preservation and conservation of land as ways protect land for recreation and aesthetic purposes (Figure 2). Most recently in 2012, Brevard established the Bracken Preserve through a conservation easement and opened the land for light recreation purposes ("Bracken Preserve" n.d.). However, with a national park, two national forests, a state forest, and several local conservation easements, WNC has a significant amount of protected land. Local governments may be wary to set aside more land as the population continues to grow.

Another best practice in biological conservation is ecological restoration and reconstruction. Ecological restoration consists of "repairing small-scale damage to landscapes tattered by human land uses" (Handel et al. 2013, 667). The Chicago Wilderness and its Biodiversity Recovery Plan are a leading example of habitat restoration. The plan focuses on greening infrastructure, restoring nature, climate change mitigation, and educating residents about the benefits of outdoors (Heneghan et al. 2013). Scholars agree that it is important to pair ecological reconstruction with a human component, such as an education program, a tourist destination, or a visible cost reduction. This combination results in greater support and likelihood for project implementation. However, mitigating the damage humans can cause in the newly restored habitats requires careful planning.

Even an urbanizing area can still find ways to pursue habitat reconstruction. Flat Rock, NC converted a local golf course into the Park at Flat Rock in 2013 (Figure 3). The landscape architect designed the park to protect and preserve indigenous species through a low impact and passive recreation space ("Park FAQ" n.d.). Many portions of the park with more active uses are still under construction as well as the reforestation of parts of the old fairways.

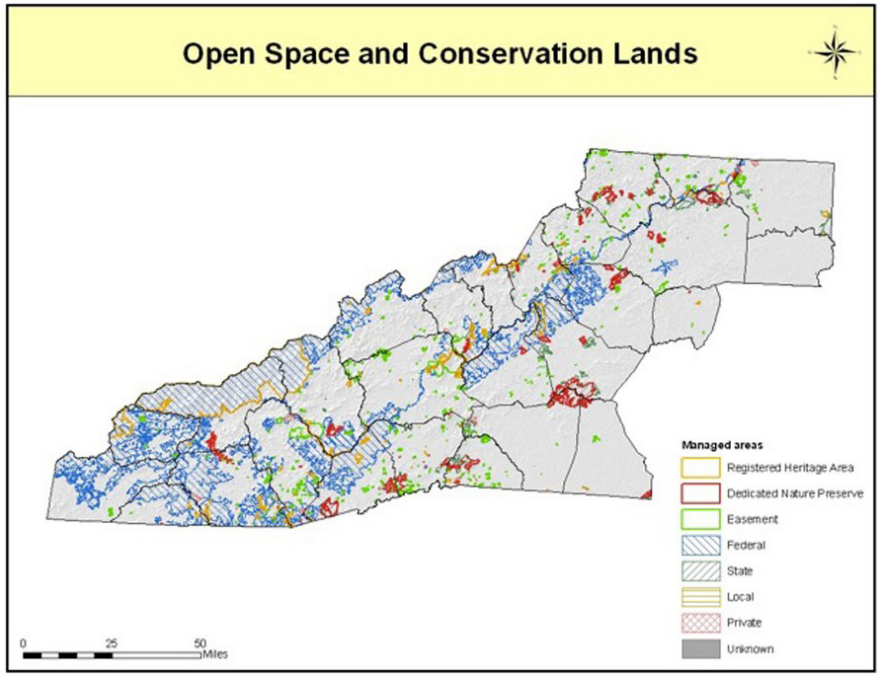

Figure 2. Open Space and Conservation Lands in Western North Carolina

Source: North Carolina Conservation Planning Tool (CPT)–Biodiversity/Wildlife Habitat Assessment. 2016. North Carolina Natural Heritage Program, NC Department of Natural and Cultural Resources. Raleigh, NC.

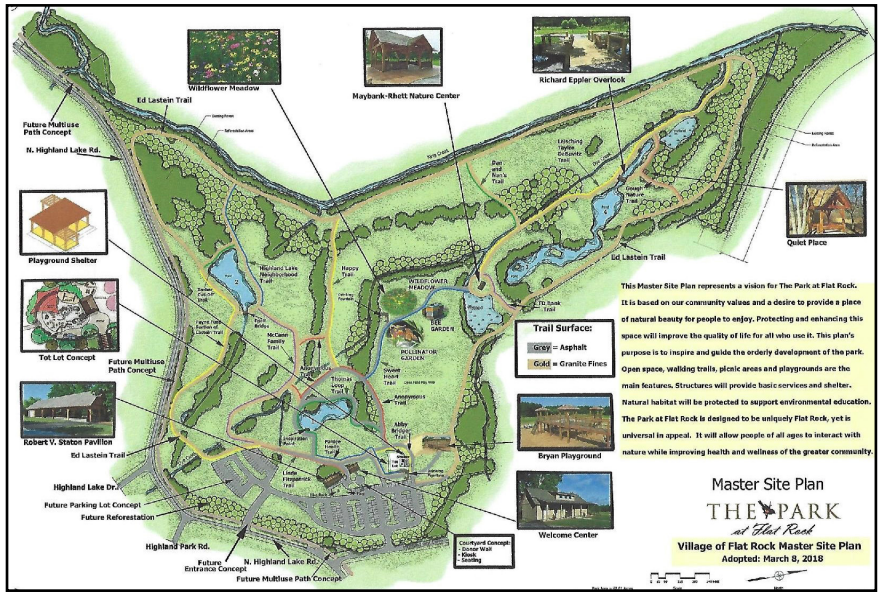

Figure 3. The Park at Flat Rock Master Plan

Source: The Village of Flat Rock. 2018. https://flatrocknc.govoffice3.com/?SEC=A7A15169-388E-4CEE-8BD9-439C4236F2C9

Overall, the park combines many of the best practices of ecological restoration.

Designing developments with conservation of trees or other habitats in mind can help protect trees, soils, and habitats during and after the development is built. Also called land conservation development, these practices can be incorporated into zoning regulations to help preserve the existing nature of the land as much as possible. This often means building closer to roads and restricting where buildings are allowed be built on a lot. Urban growth boundaries for conservation purposes act in a similar manner for entire cities (Randolph 2012). Urban growth boundaries often disproportionately negatively affect the poor of society and can lead to further environmental degradation if informal settlements and slums develop (McDonald et al. 2013).

The Farm at Highland Lake Village is a current development project in Henderson County using conservation zoning practices (Figure 4). The development contains 20 lots around one acre in size with requirements for almost two-thirds of each lot to remain undeveloped forest and open space. The houses cluster around a farm in which the residents will be members of a farm share program (Highland Lake Village n.d.). This is a luxury development, which many inhabitants of the area would not be able to afford, but the practices could be expanded to future developments if it proves successful.

In addition to the biological conservation best practices outlined above, research and up-to-date information about the condition of biodiversity, ecosystems, and species are crucial for governments to recommend policies and write legislation regarding development and habitat protection. The North Carolina General Assembly established the Mountain Resources Commission (MNC) as a non-regulatory organization in 2009. The MNC is tasked with providing WNC-specific data to local governments to allow them to make better informed decisions on resource use and community planning (UNC Asheville's NEMAC 2016).

Current Methodology for Studying Future Impact

The three sections above address the importance of protecting biodiversity from the effects of urbanization as well as best practices for biological conservation, but how can

Figure 4. The Farm at Highland Lake Village Concept Master Plan

Source: Highland Lake Village. 2018. http://www.highlandlakevillage.com/pdf/sales.pdf

local governments and institutions know where to best allocate resources and initiatives? They cannot preserve all undeveloped land, especially in areas with significant private land holdings such as the eastern seaboard of the United States. Scholars have begun using land use projections and existing biodiversity data to determine the critical intersections that planners should monitor and act upon through preservation, conservation, or sustainable development measures (Güneralp and Seto 2013; Seto et al. 2012; Hak and Comer 2017; Weller 2017).

Seto et al. (2012) performed a probabilistic analysis and developed spatially explicit urban growth forecasts out to 2030 in two phases that accounted for population and GDP projections. The scholars then overlaid biodiversity hotspot, endangered species, and carbon pool datasets to determine where urbanization would affect these critical habitats and ecosystem services. Biodiversity hotspots are regions with more than 1,500 endemic species of vascular flora and where 70 percent of the habitat has been lost (Myers et al. 2000). The endangered species data set primarily focused on species that are confined to small areas (Seto et al. 2012). This study provides a global overview of the areas of greatest concern for urbanization affecting biodiversity, but it ignores areas with high biodiversity without large amounts of habitat degradation. While it is crucial to protect those areas most endangered, policy-makers in all urban areas must become proactive about conserving the biodiversity and ecosystem resources closest to them.

Güneralp and Seto (2013) studied the impact of global forecasts of urban expansion on protected areas. Using the urban growth forecasts methodology developed by Seto et al. (2012), the model

included an exclusion layer for the known protected areas around the world drawn from the IUCN-PAs. The scholars also overlaid the urban expansion forecasts with the biodiversity hotspot maps. The study addressed the critical concerns regarding the future preservation of protected areas as well as the future impacts of urbanization on areas that are most at risk for detrimental biodiversity loss (Güneralp and Seto 2013). Overall, this study is useful for highlighting the threats to biodiversity that the global community and national governments should prioritize above all others. However, scholars conducted this study at a global scale, which does not allow for local governments to take concrete actions based off the analysis. In addition, the biodiversity portion of the study was an overlay of biodiversity hotspots. It did not consider the impact to biodiversity outside of the hotspots in ecoregions with high biodiversity but less habitat loss. .

The Landscape Condition Model uses nationally available, moderate- to high-resolution spatial data to determine the relative impacts of human land uses on biodiversity (Hak and Comer 2017). The model assumes that human development and land uses affect ecological processes nearest to them and that greater distance from these land uses will cause these effects to dissipate. Hak and Comer conduct the study using overlapping data for North America because an area with more stressors would theoretically have a higher degree of environmental stress than areas that do not have as many stressors. The continental and country scale of this study allows national and regional governments to determine the areas most affected by the built environment. This is beneficial to inform policies for an entire ecoregion. While the study does not use urbanization forecasts, its assumption of higher negative impacts closer to human land uses provides a useful proxy for determining which areas should have sustainability and ecosystem-oriented policies and regulations.

Of the four methodologies analyzed, the *Atlas for the End of the World* provides local scale maps for large cities around the world. Weller (2017) created conflict maps for each biodiversity hotspot and for specific cities to identify areas where urban growth, existing landscape conditions, and habitat ranges for mammals listed on the IUCN Red List intersect. This study combines information from Seto et al. (2013) with data similar to that which Hak and Comer (2017) created. The author acknowledges that the zoomed-in city maps are at a relatively low-resolution because the urban growth forecasts were sourced from Seto et al. (2012). This is a crucial issue with the urban growth projection used in the models discussed in this section. High-resolution forecasts are necessary for local governments to make informed local-scale decisions. Low resolution maps can provide insights into major issues but make it difficult to tailor policies to specific areas.

Theory Building upon and Contributing to the Established Literature

Humans tend to settle in areas with relatively high biodiversity compared to surrounding areas, due to the abundance of ecosystem services these locations provide. Urbanization tends to degrade ecosystems and biodiversity by absorbing land into the urban matrix and fragmenting habitats. As urban areas increase in size, it is important for planners, developers, and local and regional governments to strike a balance between cities

and locations within and around the urban matrix that promote biodiversity and ecosystem services. Given the difficulty in determining the impact of specific species on ecosystem services, loss of biodiversity is seen as a proxy for loss of ecosystem services. A wealth of best practices in biological conservation exist and are being implemented in WNC. However, in order to proactively protect and maintain biodiversity, local governments need to know where projections of future development may have the largest impact on biodiversity.

This study hopes to contribute to the existing literature by providing local-scale data (100-meter resolution) regarding the potential impact of future urbanization on biodiversity. It will also consider three different development scenarios to determine whether sprawl or infill development has a larger potential impact on biodiversity.

Much of the existing applications of this kind of research focuses on the global and ecoregion scales. While Weller (2017) creates conflict maps for metropolitan areas around the world, this analysis has a 5-kilometer resolution, which makes it difficult to apply to smaller urban areas. In addition, Houston and Los Angeles are the only metropolitan areas in the United States to which Weller (2017) has applied this analysis.

The literature surrounding this type of methodology overwhelming studies biodiversity hotspots. The Southern Appalachian Mountains ecoregion also contains high biodiversity (over 2,250 endemic vascular species), which will be impacted by urbanization as the population of human inhabitants continues to grow. It is important to study and act now to prevent the mountain region from becoming a biodiversity hotspot.

Western North Carolina is an ideal location to study where future development may impact biodiversity. The population and urban/suburban land use are growing rapidly, but the inhabitants often move to the area because they enjoy the aesthetic environment or the outdoor recreation opportunities the area provides. The cities are relatively small and theoretically have the ability to implement policies quickly to protect the environment and ecosystem services for future generations. As shown above, the cities already have implemented best practices and relatively new theories for conserving the natural environment. The results of this analysis will allow local governments to make informed decisions about future land use and development.

METHODOLOGY

This study determines the potential impact of future urbanization on biodiversity in the Asheville-Brevard Combined Statistical Area (CSA). In order to analyze this impact, I create conflict maps by modifying the methodology outlined by the *Atlas for the End of the World* (Weller et al. 2017). The analysis uses three scenarios of urbanization through 2035 generated by the FUTure Urban-Regional Environment Simulation (FUTURES) model and the North Carolina Biodiversity and Wildlife Habitat Assessment to determine the conflict zones between highly sensitive land and projected future development.

Conflict Map Methodology

This study models its conflict maps off the biodiversity conflict maps developed by Weller et al. (2017). Weller et al. (2017) produced a series of conflict maps for each of the biodiversity hotspots in the world as well as 33 of the largest and fastest growing cities within the hotspot regions. Houston and Los Angeles are the only U.S. cities included in their more detailed analysis of 33 cities. The scholars overlay projected growth trajectories through 2030 gathered from the Seto Lab at Yale with data on protected areas, remnant vegetation and the IUCN Red List of Threatened Species. The areas where these two types of data intersect result in conflict zones. Figure 5 provides an example of how data is overlaid and symbolized.

While the above methodology is a useful starting point, the hope of this study is to provide more context specific and fine-grained conflict maps. Weller et al. (2017) use urbanization forecasts with a resolution of 5km for their conflict maps. A 5km resolution offers the ability to determine large swaths of land where future development may occur. This resolution is useful for cities with large landmasses and populations, but it is not readily applicable to the Asheville-Brevard CSA. Five kilometers is too low of a resolution to determine where future development will occur due to the relatively small population and urban area compared with the largest cities in the world. Therefore, this study needs a higher resolution of urban forecasts to conduct analysis and provide recommendations.

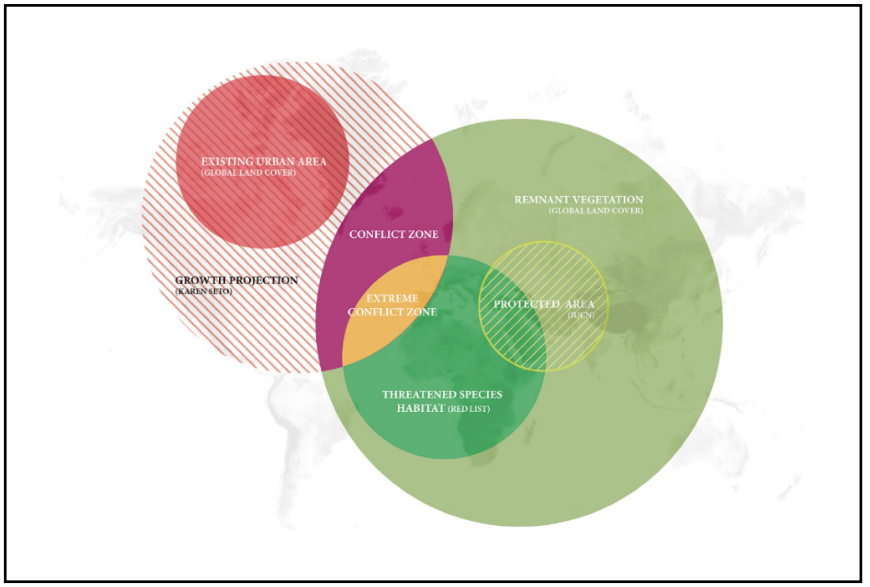

Figure 5. Overlay Mapping Method from the Atlas for the End of the World

Source: © 2017 Richard J. Weller, Claire Hoch, and Chieh Huang, Atlas for the End of the World, http://atlas-for-the-end-of-the-world.com

In addition to the scalability issue of the *Atlas for the End of the World* methodology, Weber et al. (2017) merely overlay the datasets rather than intersecting them. Their analysis is not able to provide details on how much development is projected to occur as well as the total area of the conflict zones. This study adopts the following methodology in ArcGIS to generate the conflict maps for the Asheville-Brevard CSA (Figure 6):

1. Reclassify and convert rasters of both scenarios of projected development through 2035 and the biodiversity assessment into polygons.
2. Create a fishnet layer with 100m2 grid cells and use a spatial join to generalize the projected development and the biodiversity assessments.
3. Join the biodiversity assessment fishnet with each projected development scenario fishnet.
4. Create a dataset for each county in the Asheville-Brevard Combined Statistical Area.
5. Generate summary statistics and export attribute tables to Excel.

Data Sources

This study uses the North Carolina Wildlife and Biodiversity Assessment and urbanization forecasts using the FUTURES model created by Meentemeyer et al. (2013).

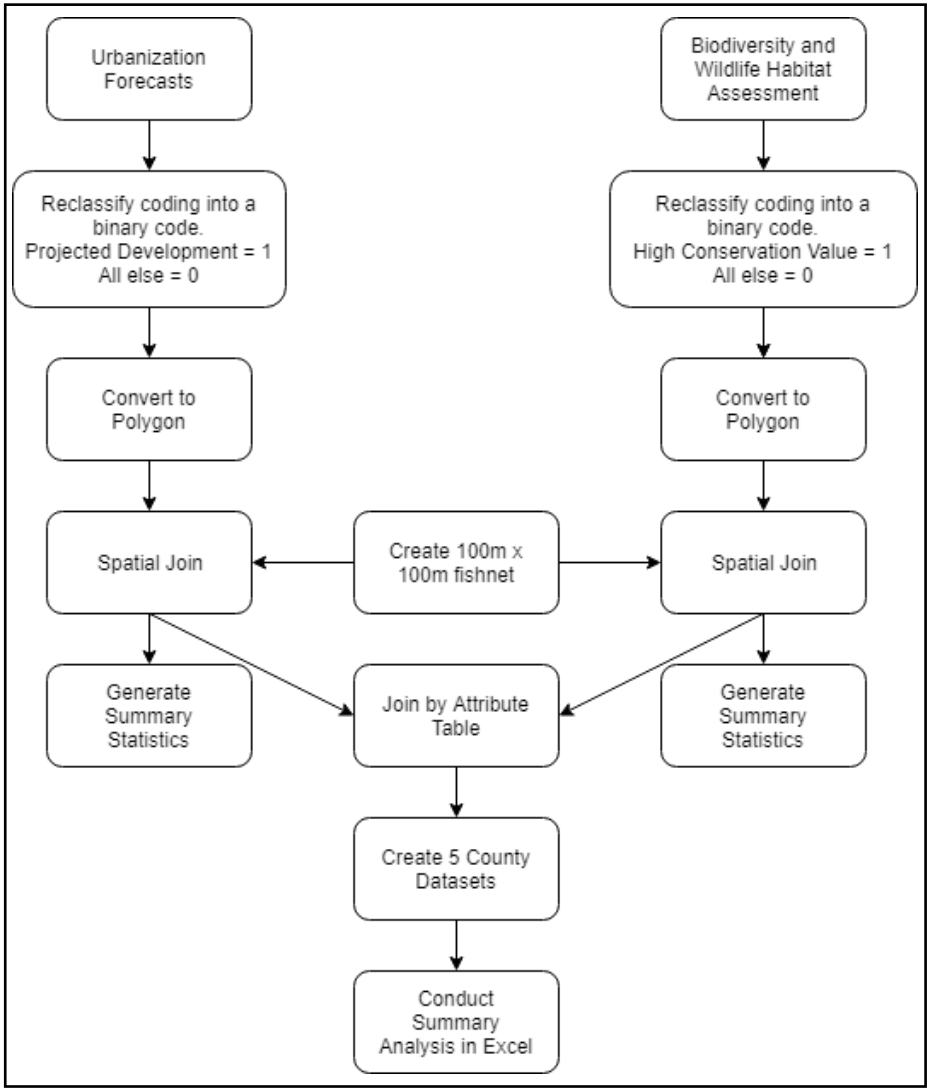

Figure 6. Conflict Map Methodology

North Carolina Wildlife and Biodiversity Assessment

The NC Wildlife and Biodiversity Assessment is a 30-meter resolution raster dataset available through the North Carolina Conservation Planning Tool. The Assessment creates a categorical ordinal scale of the relative conservation value of land in North Carolina. Pixels with a ranking of 10 provide the highest relative conservation value, and pixels with a ranking of 1 have a moderate relative conservation value. Figure 7 shows the biodiversity assessment within the five-county study area. Rather than using multiple datasets to create overlays where conflict zones are areas that intersect with remnant vegetation and extreme conflict zones exist when remnant vegetation and threatened species are present, the Assessment combines multiple datasets to provide this ranking. Therefore, this study does not need to include multiple datasets in the conflicts maps to represent biodiversity.

The Assessment focuses on aquatic and terrestrial habitats, connectivity, and current landscape function. The ranking is intended to preserve the areas with the highest ecological significance and distinction, and for which data is more specific and reliable. The raster combines the ordinal rankings of multiple datasets (Table 1). The final ranking uses the highest value that exists for each pixel. The researchers evaluated each input dataset for how important/valuable the data was and then they ranked the datasets.

One issue with this composition is that it may produce results heavily biased toward the most complete dataset used to create the ranking. For example, the assessment gives Significant Natural Heritage Areas a higher ranking because they provide the greatest fine scale data for biodiversity. However, the data exists for relatively small, protected land. The assessment may not account for other areas—protected or otherwise—with needs for conservation due to high biodiversity. Lack of data availability may skew rankings in favor of areas where data that is more complete exists.

Key to Identify Tool Results for the Biodiversity/Wildlife Habitat Assessment			
Category Name	**Value**	**Individual Input Layers**	**Source for Input Layers**
NHP	10	Natural Areas – Exceptional and Very High Site Rating	*N.C. Natural Heritage Program*
	8	Natural Areas – High and Moderate Site Rating	
	6	Natural Areas - General Site Rating	
	5	Element Occurrences – High ranking	
	4	Element Occurrences – Other	
Wetlands	7	Coastal Region Evaluation of Wetland Significance (CREWS) – Exceptional	*N.C. Division of Coastal Management*
	6	Coastal Region Evaluation of Wetland Significance (CREWS) – Substantial	
	5	National Wetland Inventory (NWI)	*U.S. Fish and Wildlife Service*
	2	Coastal Region Evaluation of Wetland Significance (CREWS) – Beneficial	*N.C. Division of Coastal Management*
Guilds	1-10	Landscape Habitat Indicator Guilds	*N.C. Natural Heritage Program*
DWQ	10	Outstanding Resource Waters	*N.C. Division of Water Resources*
	9	Stream BioClassification – Excellent	
	8	High Quality Waters	
	7	Stream BioClassification – Good	
	1	All other streams	
Fish Habitat	9	Wild Brook Trout	*N.C. Wildlife Resources Commission*
	8	Anadromous Fish Spawning Areas	*N.C. Division of Marine Fisheries*
Fish Nursery	8	Fish Nursery Areas	*N.C. Division of Marine Fisheries*
Watersheds	7	Stream buffer tributaries to federally-listed species (Threatened & Endangered)	*N.C. Natural Heritage Program*
	3	Priority Watersheds	*N.C. Natural Heritage Program, N.C. Wildlife Resources Commission*
Marine	8	Oyster Sanctuaries	*N.C. Division of Marine Fisheries*
	6	Submerged Aquatic Vegetation (SAV)	
Hardbottom	8	Open Shellfish/Shellbottom	*N.C. Division of Marine Fisheries*
	7	Hard Bottom	
	5	Closed Shellfish/Shellbottom	
IBA	6	Important Bird Areas	*Audubon Society*
Impervious	-1	Impervious Surface above 20%	*U.S. Environmental Protection Agency*

Table 1. Legend for the Biodiversity/Wildlife Habitat Assessment

Source: Wojcik, Meredith. 2018. North Carolina Natural Heritage Program Conservation Planning Tool. https://files.nc.gov/dncr-nhp/ConservationPlanningToolReport_2018update.pdf

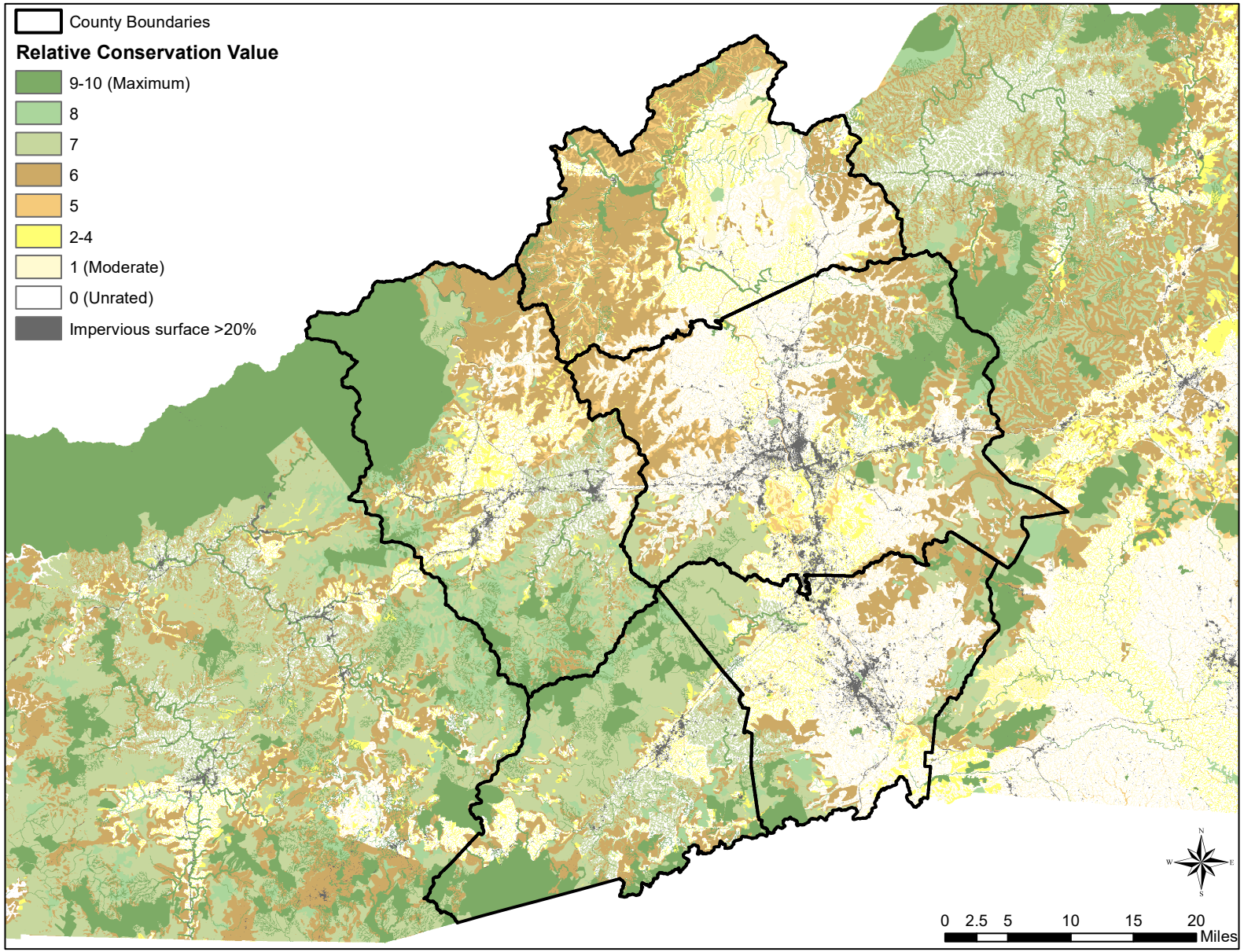

Figure 7. North Carolina Biodiversity and Wildlife Habitat Assessment in the Asheville-Brevard Combined Statistical Area

Urbanization Forecasts

As discussed above, the projected growth trajectories developed by the Seto Lab at Yale have a resolution of 5 kilometers. Therefore, this study uses the FUTure Urban-Regional Environment Simulation (FUTURES) multi-level modelling framework to generate three urbanization forecasts—baseline, infill, and sprawl (Meentemeyer et al. 2013). The FUTURES model uses GRASS GIS (an open source GIS) to house the model. The following inputs are required for the model: NLCD datasets for 1992, 2001, 2006, and 2011; elevation data; transportation network; county boundaries; protected area boundaries; city point data; and county population projections. The model produces projections of land use patterns that integrate per capita demand, site suitability, and the spatial structure of conversion events.

The Center for Geospatial Analytics at NC State University conducted a workshop titled *Spatio-temporal Modeling with Open Source GIS: Application to Urban Growth Simulation using FUTURES* in Asheville on April 3, 2016 (Meentemeyer 2016). The workshop focused on generating projections for the Asheville-Brevard CSA through 2035. I followed the instructions for this workshop to create the projection scenarios used in the conflict maps.

The main issue with the FUTURES model is that it generates small, scattered patches of potential development. This is due to the 30m resolution of the NLCD layers. It is more likely that future development will occur in the immediate region surrounding the initial patch rather than exactly where the patch appears. In addition, there is no guarantee the patch will be developed.

There are two ways to address the scale issue. One solution is to apply a buffer around each patch based on the idea that urban development in one patch will also affect biodiversity outside of the patch. However, there is a lack of information pertaining to the appropriate size of a biodiversity degradation buffer. *The Planner's Guide to Wetland Buffers for Local Governments* recommends a 300-foot buffer around wetlands to protect the ecosystem (Environmental Law Institute 2008). Perhaps scholars can apply a 300-foot buffer around projected development to determine a wider area of adverse impacts on ecosystems.

Combining or generalizing the patches at a smaller scale is the other solution to the scale issue. This option allows the researcher to determine both larger potential areas for development as well as the percentage of the patch where development may occur. This is particularly useful for creating a scale to prioritize patches that have a higher amount of projected development. Applying a buffer would not provide this ability.

This study spatially joins the projected development scenarios and the biodiversity assessment to at fishnet with 100 m^2 grid cells. It then determines what percentage of the grid cell contains projected development or land with a high conservation value.

Conclusion

The conflict maps created by Weller et al. (2017) inspire the methodology discussed above. The methodology tries to address scale issues as well as analysis capability that the *Atlas for the End of the World* conflict maps do not provide. It is important to know both where development is projected to occur as well as how much land will be converted. Therefore, we must be able to see the results as maps as well as quantitatively. The Data Analysis section will look at both of these priorities.

DATA ANALYSIS

The goal of this study is to determine where projected development intersects with land characterized by a relatively high conservation value. The three different scenarios used in the analysis have different potential impacts on biodiversity, in both location and the amount of land at risk. This analysis will first discuss the amount of non-protected land in the Asheville-Brevard CSA that has a high conservation value. Second, it describes the location and amount of projected development in each urbanization scenario—business-as-usual, infill, and sprawl. Third, it analyzes the location of the conflict zones between projected development and highly sensitive land and the amount of land in question.

Biodiversity and Wildlife Habitat Assessment

A significant amount of non-protected land (59.98%) in the Asheville-Brevard CSA has a relatively high conservation value, as seen in Table 2. This calculation includes all pixels containing any percentage of land with a high ranking in the NC Biodiversity and Wildlife Habitat Assessment (a ranking greater than 5). Protected land, such as national and state forests, is not included in the analysis as the FUTURES model excludes it from the development scenarios. Figure 8 shows the spatial distribution of land where more than 50 percent of the grid cell contains highly sensitive land.

In all counties, the large patches of highly sensitive land is located closer to the protected areas. These patches tend to be forested. Buncombe, as the largest county, contains the most land where the majority of the pixel is in high need of conservation (759.20 km^2). However, 78.39 percent of the non-protected land in Transylvania County (406.02 km^2) has a high conservation value. In all counties, there are several areas where highly sensitive land is located close to the 2011 developed land.

% of Grid Cell	Buncombe	Haywood	Henderson	Madison	Transylvania	Total Area
0.00	663.74	215.81	453.89	385.55	95.25	**1809.70**
< 20.00	--	0.01	--	--	0.04	**0.05**
20.00	0.01	0.14	0.02	0.16	0.09	**0.42**
25.00	0.29	1.49	0.35	0.92	1.77	**4.79**
28.57	--	--	--	--	0.01	**0.01**
33.33	5.36	12.47	4.79	13.23	14.72	**50.27**
40.00	0.07	0.13	0.06	0.04	0.07	**0.38**
42.86	0.01	--	0.01	--	--	**0.02**
50.00	277.38	224.69	151.15	224.89	163.16	**1036.46**
57.14	0.01	0.01	--	0.02	--	**0.04**
60.00	0.11	0.14	0.08	0.11	0.04	**0.47**
62.50	--	--	0.03	--	--	**0.03**
66.67	46.12	19.34	22.90	30.42	5.45	**123.75**
71.43	--	--	--	0.01	--	**0.01**
75.00	6.75	3.18	3.25	4.64	0.78	**18.50**
80.00	0.73	0.35	0.23	0.41	0.08	**1.79**
83.33	0.02	0.02	0.04	0.04	0.01	**0.13**
100.00	428.08	355.83	195.60	269.49	236.50	**1474.72**
Total Km^2	**1428.68**	**833.60**	**832.40**	**929.94**	**517.98**	**4521.54**

Table 2. Land with a High Conservation Value in Asheville-Brevard CSA (in km^2)

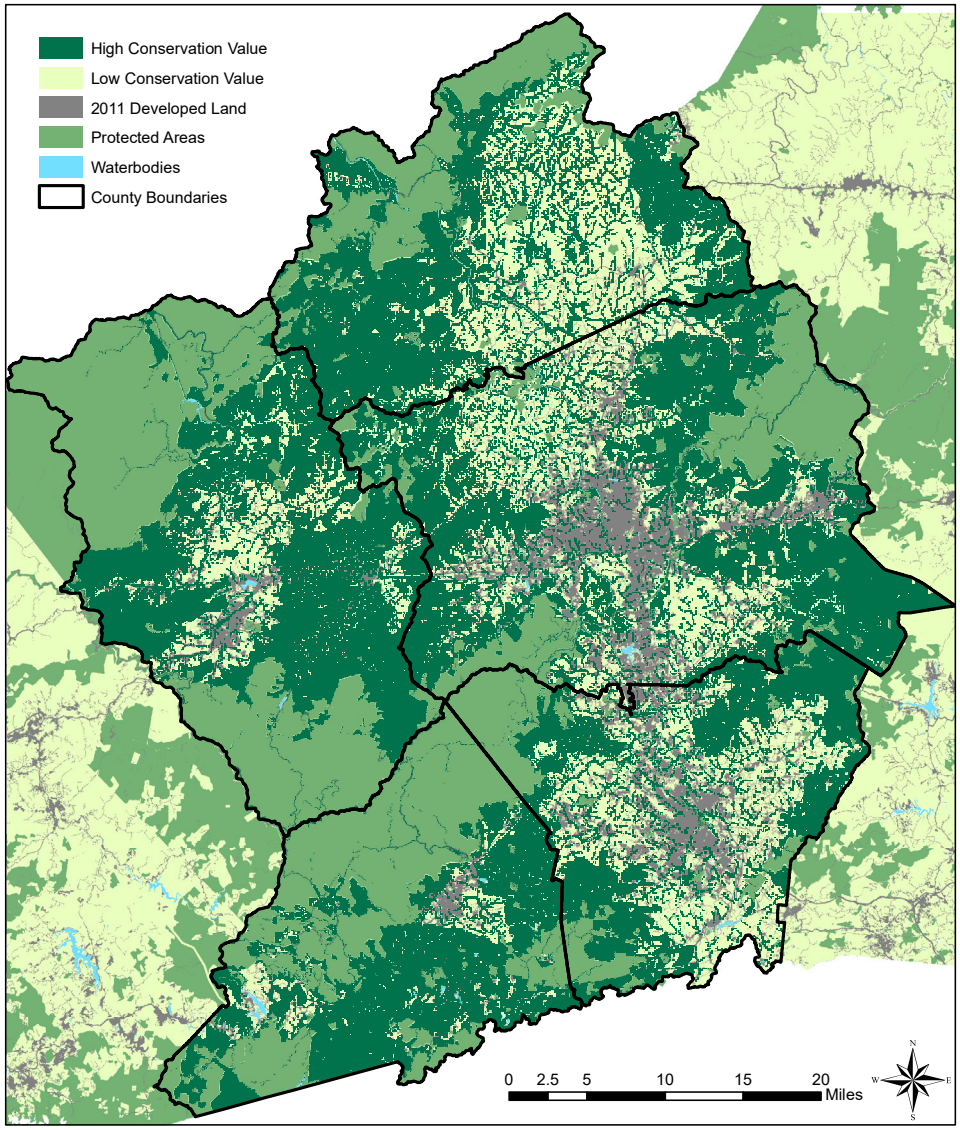

Figure 8. Land with a High Conservation Value in the Asheville-Brevard Combined Statistical Area

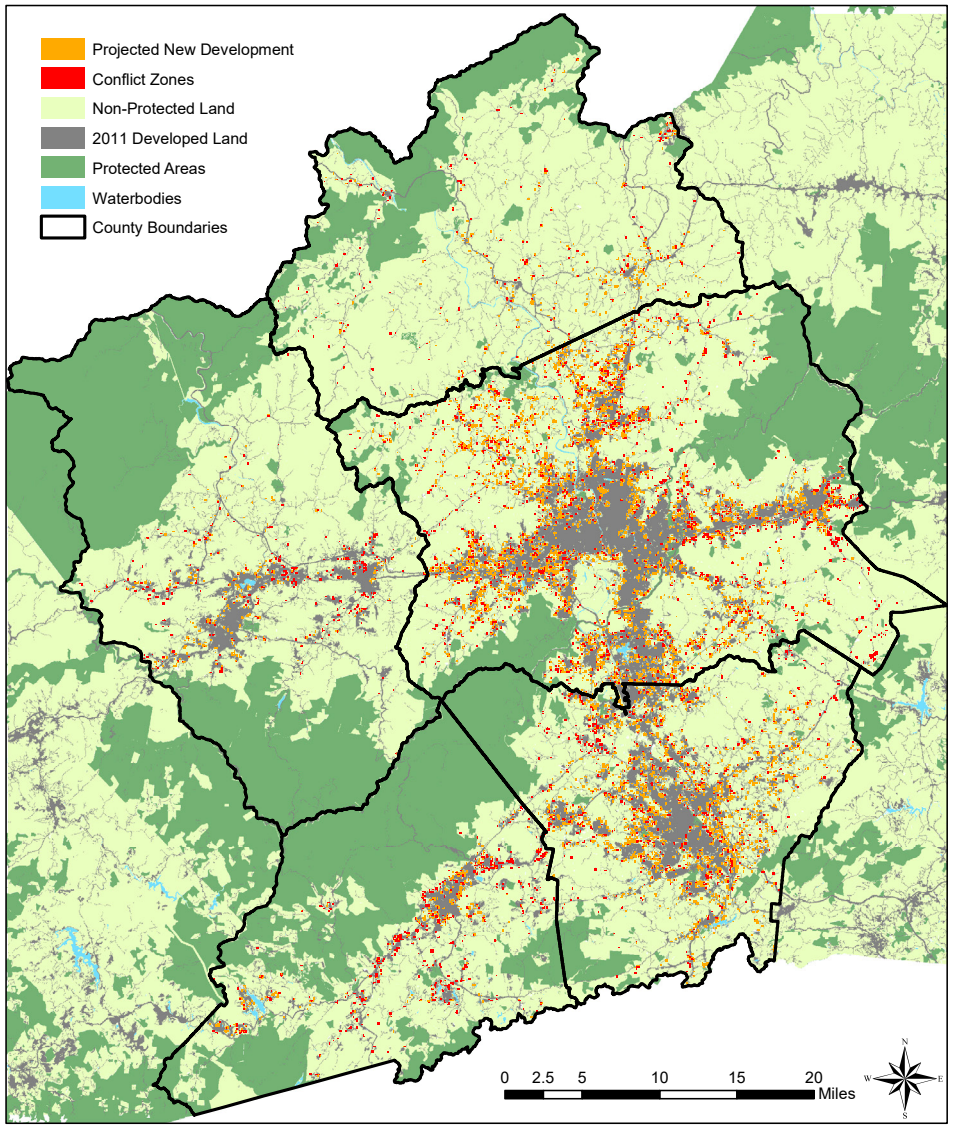

Figure 9. Business-as-usual Projected New Development and Conflict Zones in the Asheville-Brevard CSA

The Business-as-usual Scenario

The projected new development in the business-as-usual scenario is a combination of both sprawl and infill based on past development patterns (Figure 9). The projected development sprawls out from the 2011 developed land and major roads. There are very few patches generated without a cluster of patches nearby.

There are relatively few areas of projected development where 100 percent of the grid cell is forecast to have a land use change (Table 3). Most common is for 0 percent of the pixel to be projected new development. This is understandable because the fishnet generation coded all non-protected land that did not change to projected development in the FUTURES model as zero. The second most common amount of development in the grid cell is 50 percent with 192.01 km^2. This means that while the projected new development clustered in areas, the potential for dense development is rare. However, it is important to note that only the percentage of projected new development is represented within the pixel could be either existing 2011 development or non-protected land.

Buncombe County and Henderson County have the largest amount of projected new development with a majority grid cell percentage, at 115.84 km^2 and 53.43 km^2, respectively. The FUTURES model generates patches based on projected populations for each county, so Buncombe and Henderson counties always have the most projected development.

A conflict zone is defined as a pixel where an area of at least 50 percent high conservation value and an area of at least 50 percent projected new development intersect. In the business-as-usual scenario 33.50 km^2 of the projected new development falls in conflict areas (Table 4). This represents 15.95 percent of projected new development and 0.78 percent of the total non-protected land within the CSA. Figures 10-14 provide a large-scale view of each county.

% of New Development in Grid Cell	Buncombe	Haywood	Henderson	Madison	Transylvania	Total Area
0.00	1311.12	821.18	778.17	919.72	502.04	**4311.56**
20.00	0.01	--	--	--	--	**0.01**
25.00	0.12	--	0.03	0.01	--	**0.16**
33.33	1.60	0.10	0.75	0.03	0.14	**2.60**
40.00	--	--	0.02	--	--	**0.02**
50.00	106.02	11.88	49.54	10.01	14.94	**192.01**
66.67	9.01	0.40	3.60	0.16	0.76	**13.93**
75.00	0.49	--	0.16	--	0.04	**0.69**
80.00	0.03	--	0.01	--	--	**0.04**
100.00	0.29	0.04	0.12	0.01	0.06	**0.52**
Total km^2	**1428.68**	**833.60**	**832.40**	**929.94**	**517.98**	4521.54

Table 3. Area of Projected New Development in the Business-as-usual Scenario (in km^2)[1]

[1]This table includes the projected new development outside and within conflict zones

County	Km^2	% of Projected New Development	% of Non-protected Land
Buncombe	16.77	14.27%	1.17%
Haywood	3.05	24.56%	0.37%
Henderson	6.75	12.45%	0.81%
Madison	1.86	18.20%	0.20%
Transylvania	4.78	29.99%	0.92%
Total	**33.50**	**15.95%**	**0.78%**

Table 4. Area of Conflict Zones in the Business-as-usual Scenario

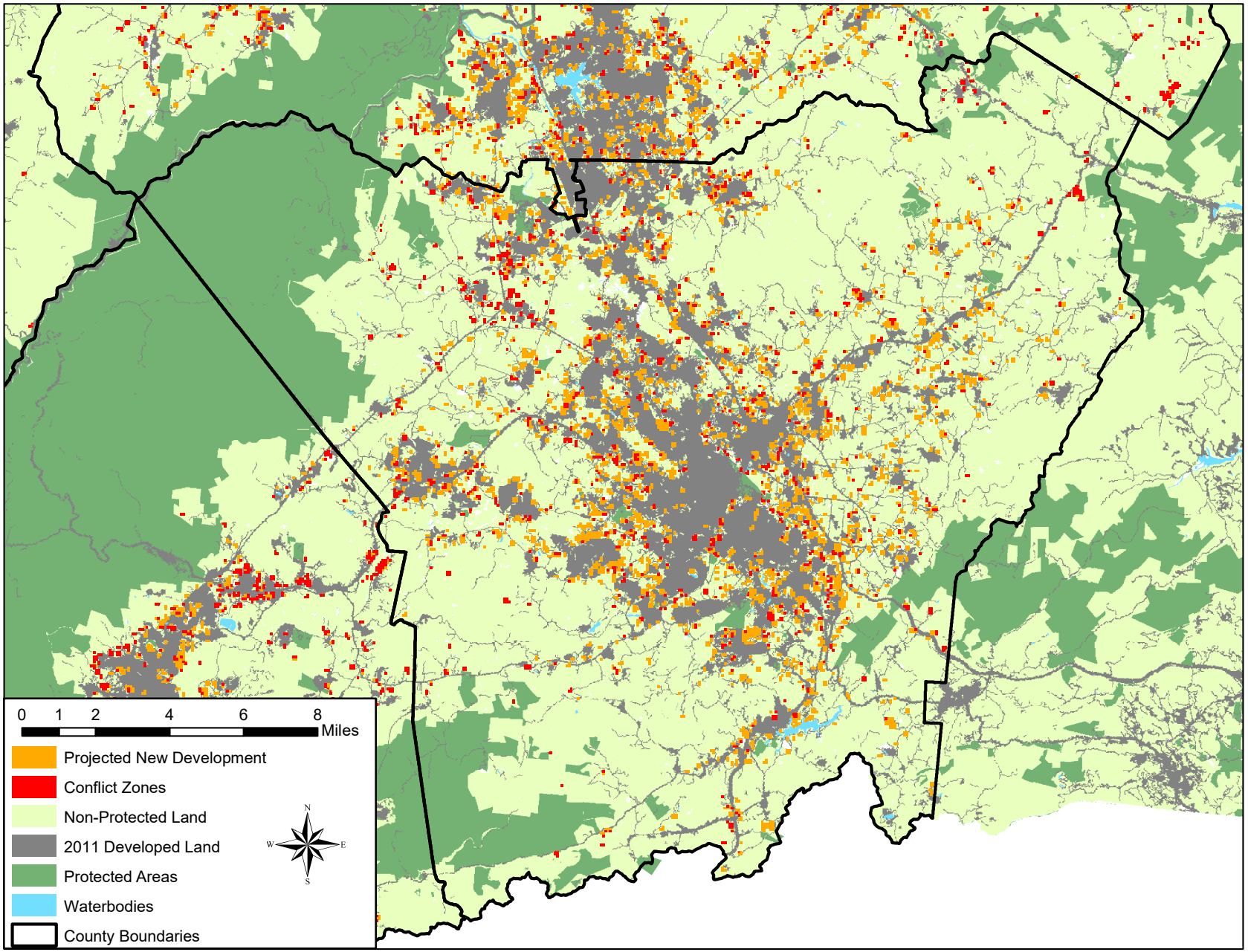

Figure 10. Business-as-usual Projected New Development and Conflict Zones in Henderson County

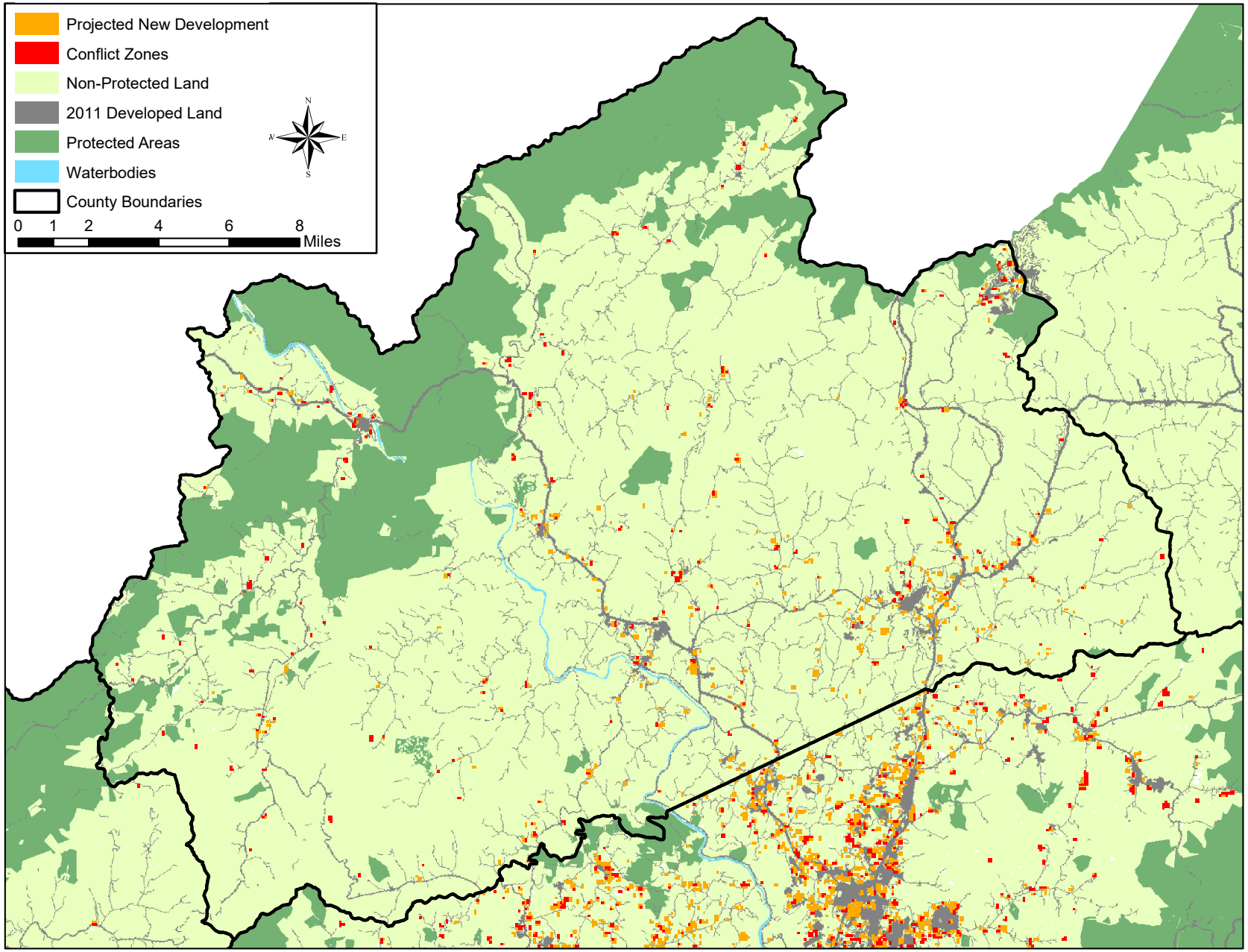

Figure 11. Business-as-usual Projected New Development and Conflict Zones in Madison County

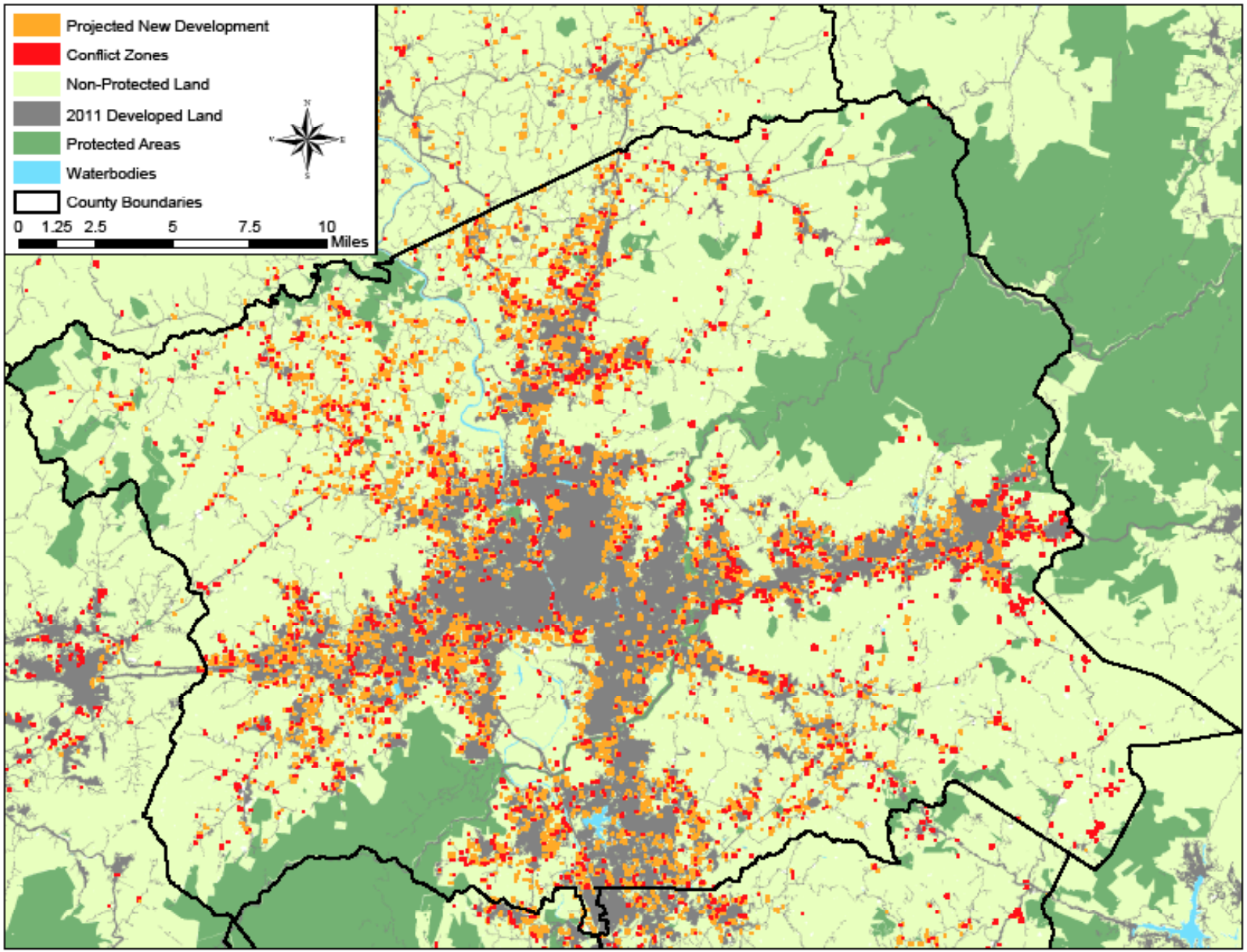

Figure 12. Business-as-usual Projected New Development and Conflict Zones in Buncombe County

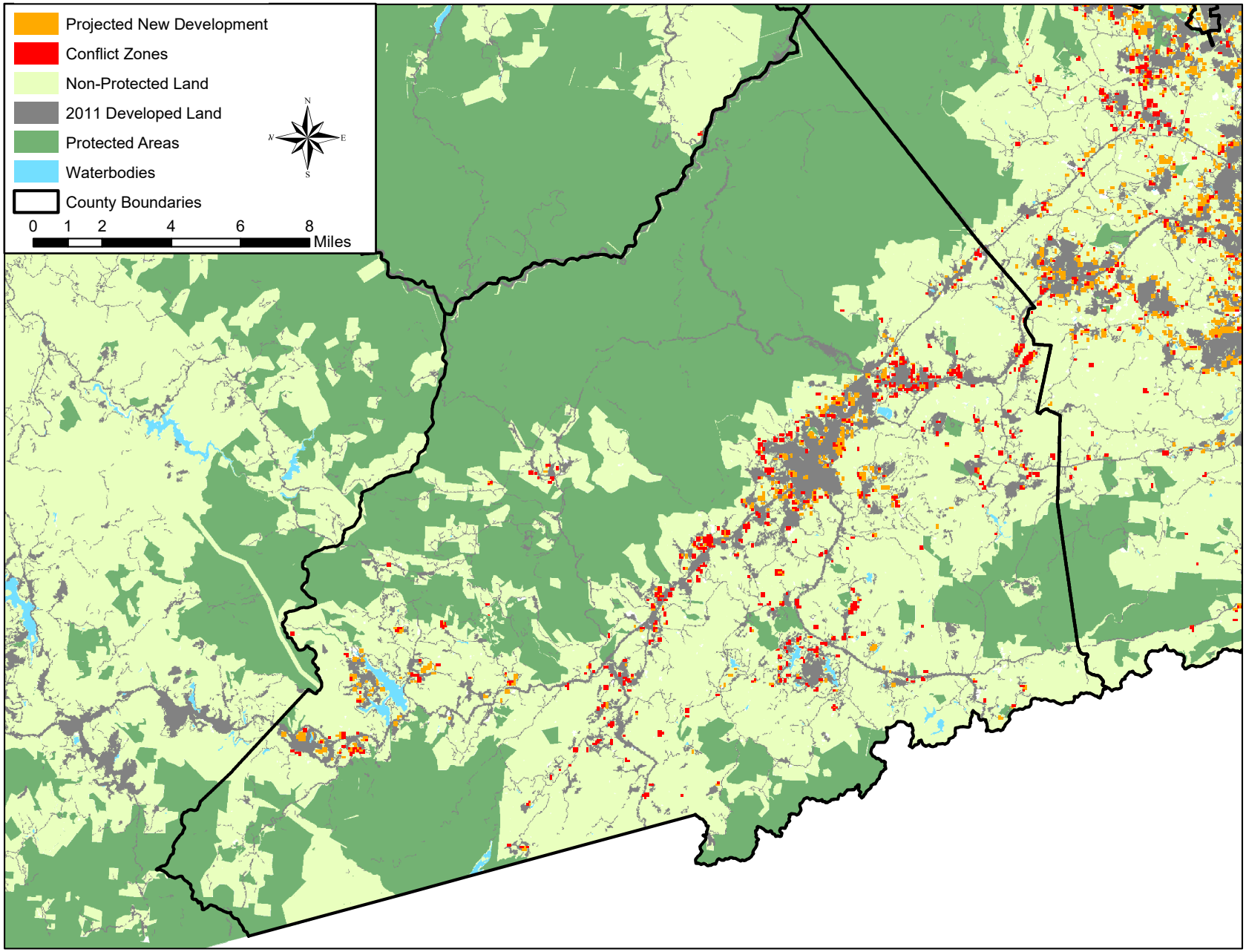

Figure 13. Business-as-usual Projected New Development and Conflict Zones in Transylvania County

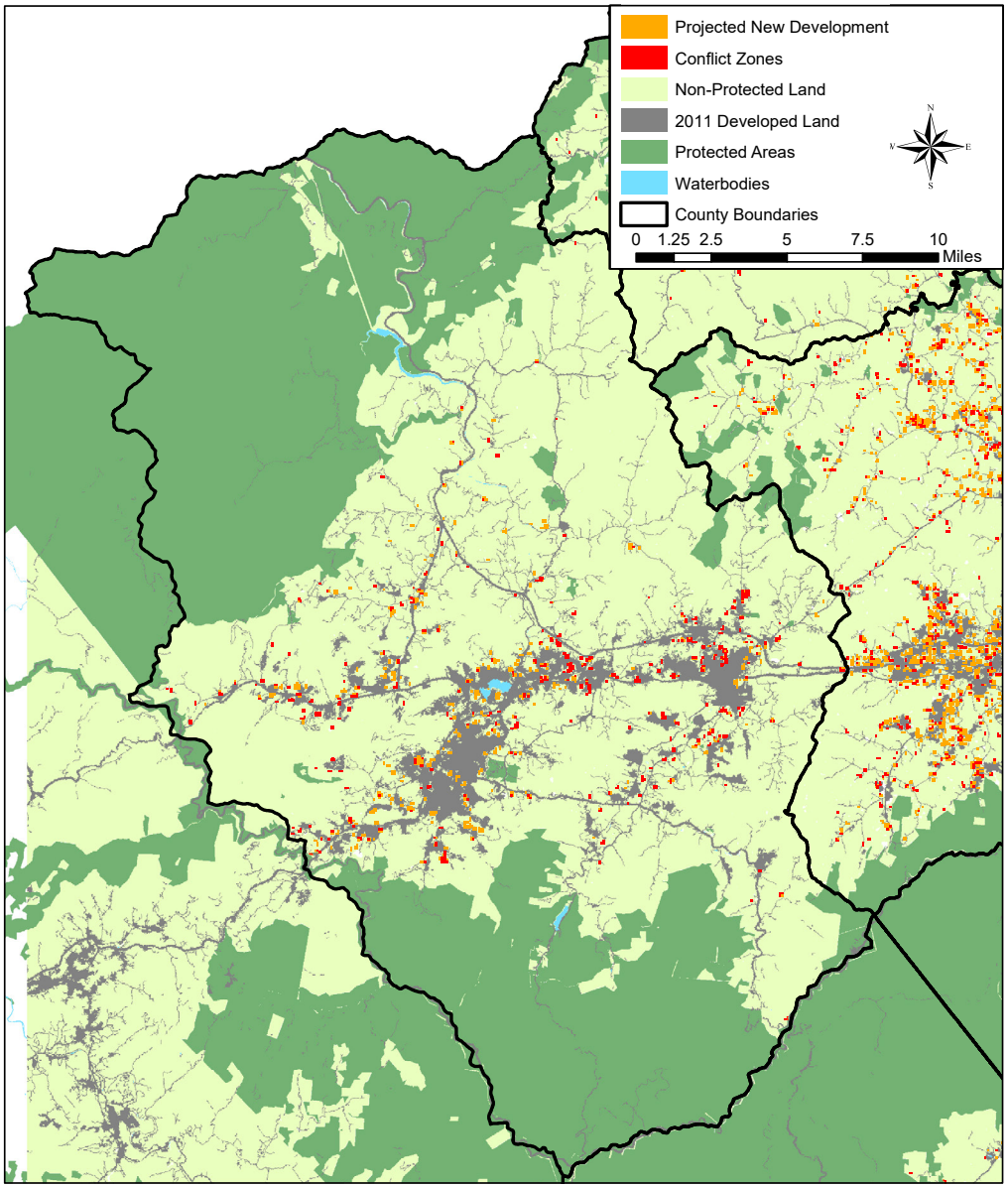

Figure 14. Business-as-usual Projected New Development and Conflict Zones in Haywood County

In the business-as-usual scenario, conflict zones tend to be located close to existing 2011 development in all the counties, but not necessarily the urban cores. However, this is most likely the effect of the how FUTURES model projected new development through 2035 based on previous land use patterns. This has an interesting effect on two of the counties: Henderson and Madison.

Henderson County (Figure 10) contains the lowest risk of new development intersecting with conflict zone (12.45%). Henderson County is an interesting case because many of the clusters of conflict zones occur closer Pisgah National Forest in the northeast of the county rather than near the urban core. This shows signs of greater sprawl in the business-as-usual case than the other counties. There are still conflict zones near the center of the 2011 development, probably due to streams and wetlands.

Madison County (Figure 11) has the smallest projected population, which the sparse amount of patches in all three scenarios reflects. However, Madison County differs from the other counties because the business-as-usual has a larger amount of conflict zones than the other two development scenarios. The use of previous development patterns as a guide causes a large portion of the projected new development through 2035 to appear in two areas of high tourist activity: Hot Springs in the northwest and Wolf Ridge Ski Resort in the northeast. Land with a high conservation value surrounds both developments as well as proximity to Pisgah National Forest.

While Buncombe County (Figure 12) has one of the lowest percentages of conflict zones within projected new development, over 1 percent of the total non-protected land in the county is

at risk within the business-as-usual scenario. Within Buncombe County, the biodiversity assessment primarily gives the land close to existing development a high conservation value because of existing streams and wetlands.

Almost 30 percent of the projected new development in Transylvania County (Figure 13) occurs in a conflict zone. This is understandable because Transylvania contains the largest percentage of highly sensitive, non-protected land. Transylvania has a large amount of protected land in the form of state and national forests, which constrains where development can occur. Planners and city officials must be aware of the potential impact that any amount of development may have on the biodiversity of the county. The projected new development close to the urban core of Brevard and Lake Toxaway, is less likely to conflict with areas of high biodiversity.

Similar to Madison and Transylvania, the conflict zones in Haywood County (Figure 14) appear in heavily forested areas near existing urban development. Almost 25 percent of the projected new development falls in a conflict zone, but this only represents 0.37 percent of the total non-protected land in the county.

The Infill Scenario

The infill scenario is created using the lowest amount of spread allowed by the FUTURES model (Figure 15). It prioritizes creating patches of development in areas closes to existing development more than following past development trends.

Similar to the business-as-usual scenario, the infill scenario projects relatively little development to cover a full 100 m^2 grid cell (Table 5).

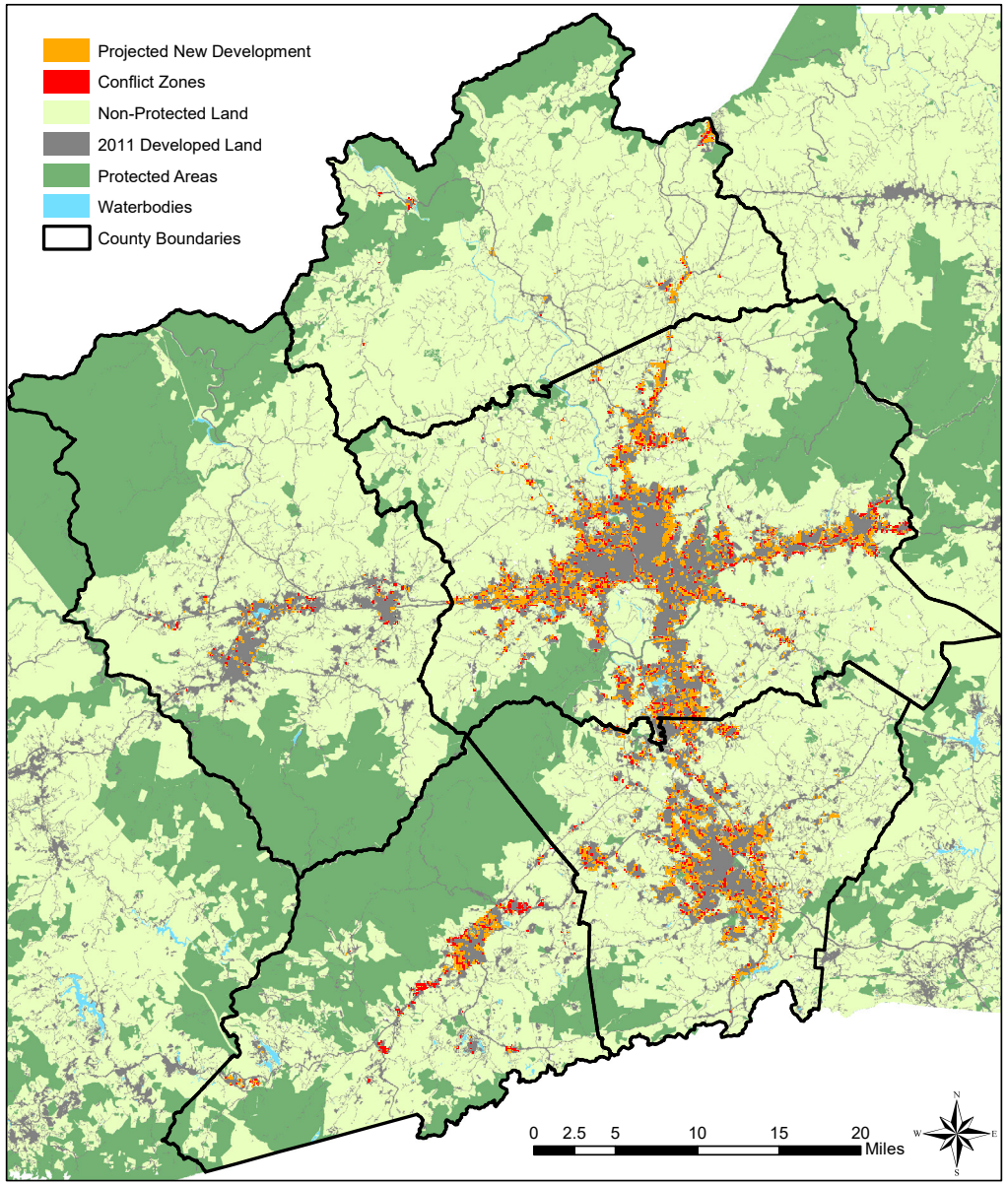

Figure 15. Infill Projected New Development and Conflict Zones in the Asheville-Brevard CSA

The most common amount of projected development in the grid cell is 50 percent with 127.71 km^2 for the whole CSA. Buncombe County has 96.66 km^2 where the majority of grid cell is projected development, and Henderson County contains 46.30 km^2. Based on these numbers, pursuing infill development will convert less land to urban uses than the business-as-usual scenario.

The infill scenario prioritizes land as close to existing development as possible, which means all of the conflict zones in this scenario are located close to the urban core. The results of the scenario differ from the business-as-usual approach by less total area of conflict zones, which leads to a smaller percentage of conflict zones compared to non-protected land (Table 6). The conflict zones also make up a smaller percentage of the projected new development.

Of the potential 167.65 km^2 of projected new development in the infill scenario, 21.24 km^2 or 12.65 percent is located in a conflict zone. This combined total is less than the business-as-usual ap-proach. But the comparison of the conflict zones as a percentage of non-protected land presents a stronger argument. Conflict zones represent 0.48 percent of non-protected land in infill scenario versus 0.78 percent in the business-as-usual scenario. Figures 16-20 provide large-scale maps of the 2035 projections in each county.

The conflict zones in Buncombe County (Figure 16) and Henderson County (Figure 17) are located near the streams and wetlands within and near the urban parts of the counties. While the two counties have the largest absolute square kilometers of conflict zones, the conflict areas are the lowest percentages of projected new development for the five counties.

% of New Development in Grid Cell	Buncombe	Haywood	Henderson	Madison	Transylvania	Total Area
0.00	1329.70	827.74	785.23	926.38	505.36	**4353.89**
20.00	0.03	--	--	--	0.01	**0.04**
25.00	0.16	0.02	0.06	--	0.02	**0.25**
33.33	2.10	0.10	0.81	0.03	0.31	**3.34**
40.00	0.04	--	0.01	--	--	**0.05**
50.00	74.97	5.25	35.96	3.01	8.94	**127.71**
60.00	0.10	--	0.08	--	0.04	**0.21**
66.67	17.92	0.44	8.38	0.43	2.50	**29.56**
71.43	0.01	--	--	--	--	**0.01**
75.00	2.75	0.03	1.60	0.06	0.64	**5.08**
80.00	0.37	--	0.15	0.01	0.13	**0.66**
83.33	0.03	--	0.02	--	0.01	**0.06**
85.71	--	--	--	--	0.02	**0.02**
100.00	0.51	0.02	0.11	0.02	0.01	**0.66**
Total	**1428.68**	**833.60**	**832.40**	**929.94**	**517.98**	**4521.54**

Table 5. Area of Projected New Development in the Infill Scenario (in km^2)[1]

[1]This table includes the projected new development outside and within conflict zones

County	Km^2	% of Projected New Development	% of Non-protected Land
Buncombe	11.50	11.62%	0.80%
Haywood	1.19	20.31%	0.14%
Henderson	5.01	10.62%	0.60%
Madison	0.46	12.92%	0.05%
Transylvania	3.08	24.41%	0.59%
Total	**21.24**	**12.67%**	**0.48%**

Table 6. Area of Conflict Zones in the Infill Scenario

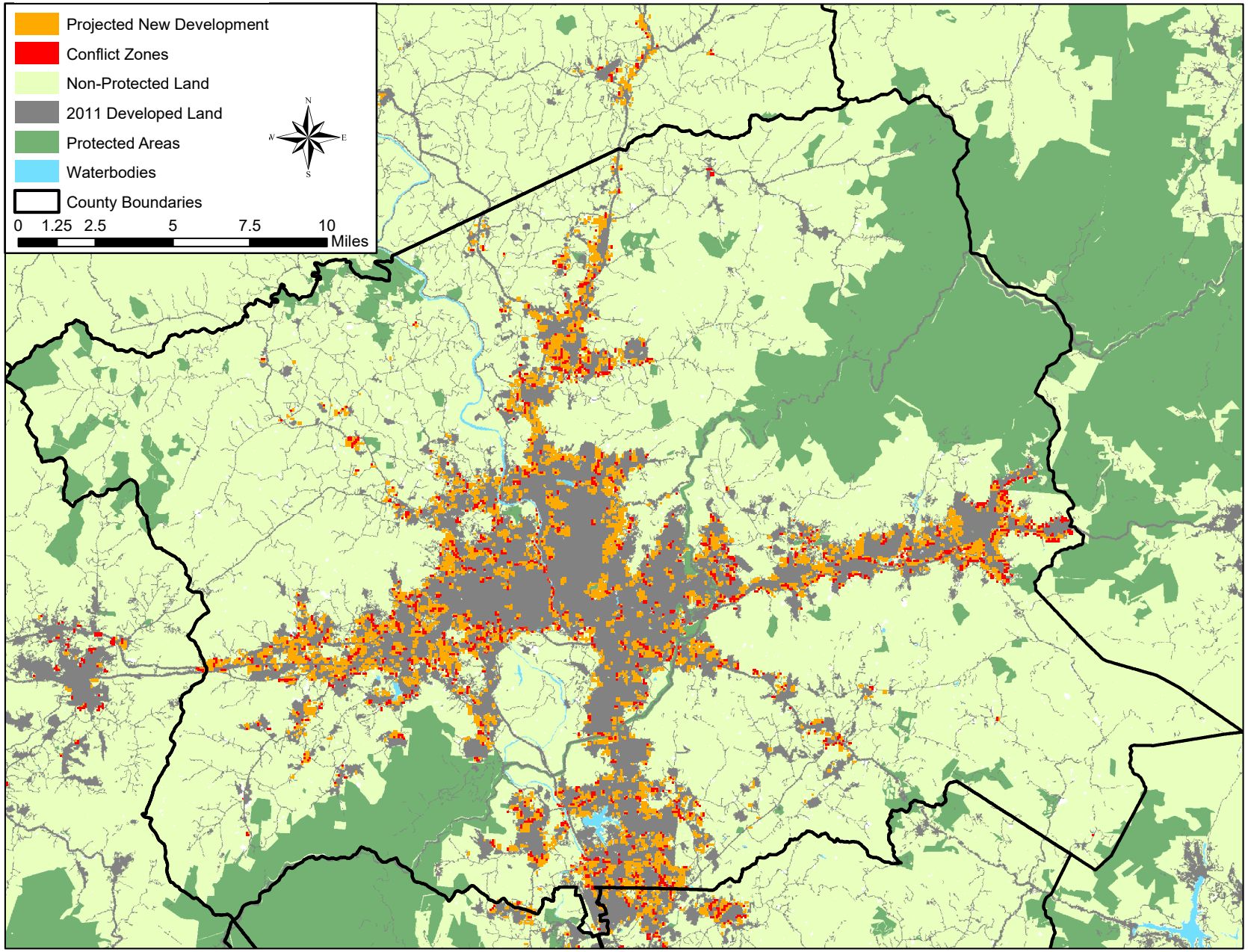

Figure 16. Infill Projected New Development and Conflict Zones in Buncombe County

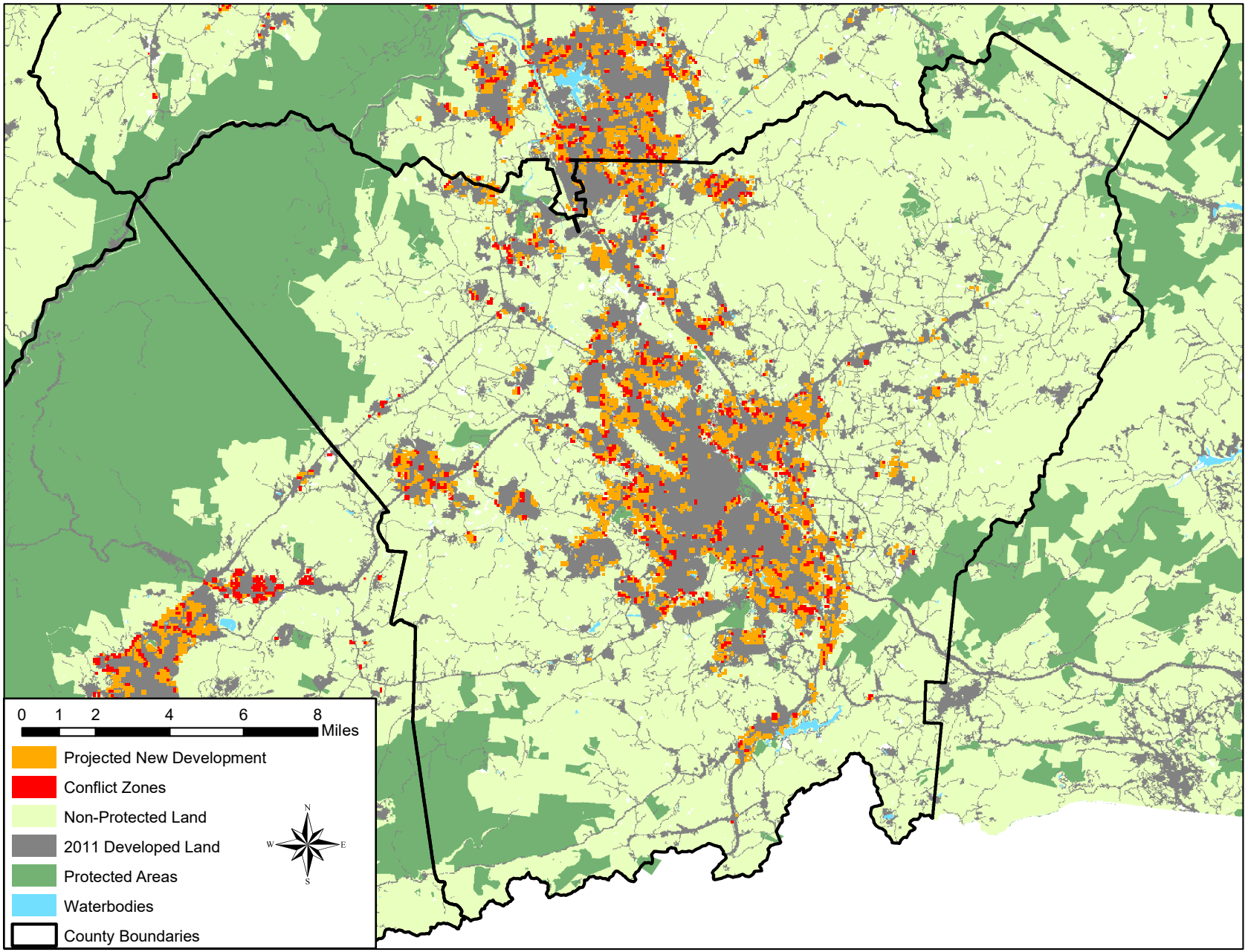

Figure 17. Infill Projected New Development and Conflict Zones in Henderson County

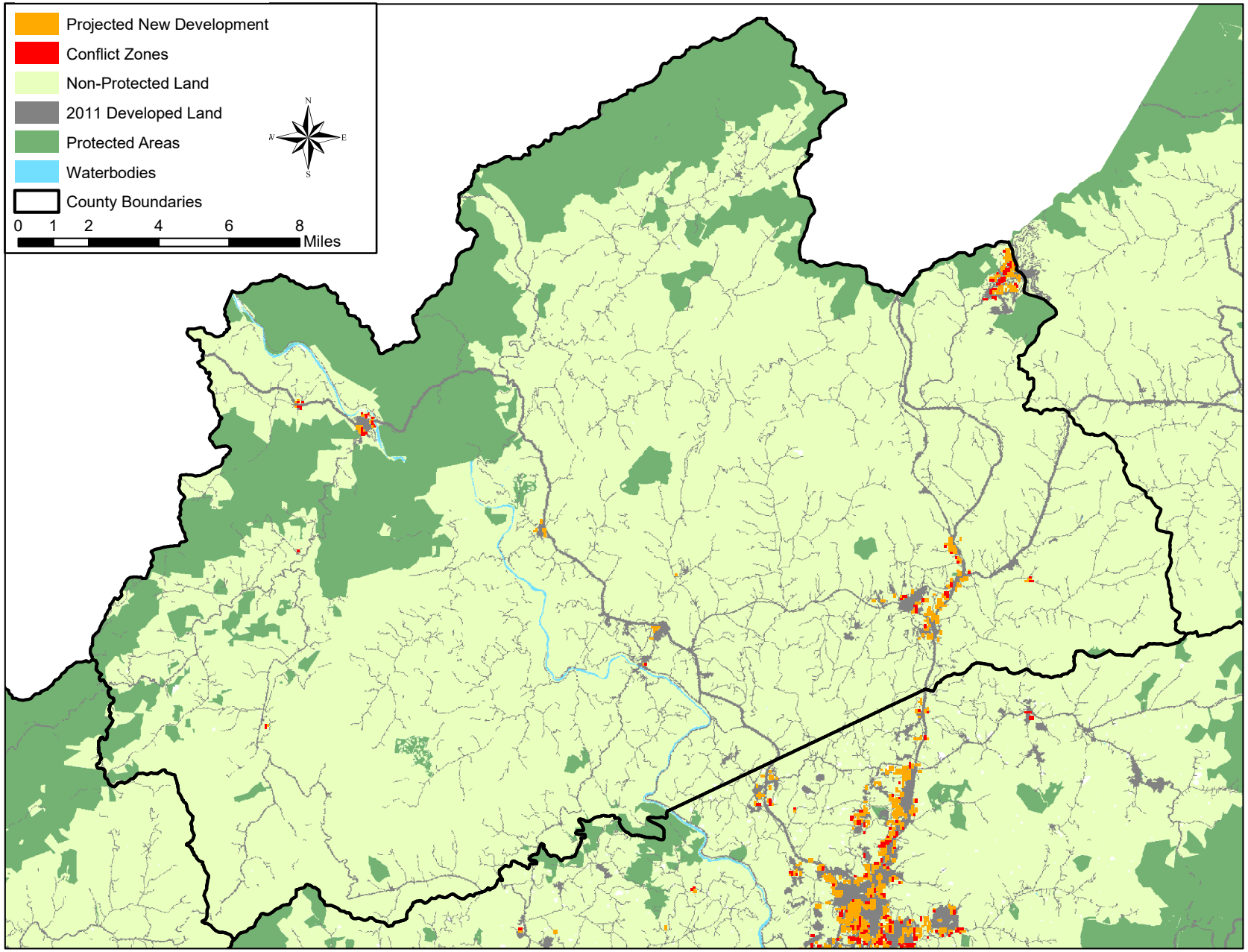

Figure 18. Infill Projected New Development and Conflict Zones in Madison County

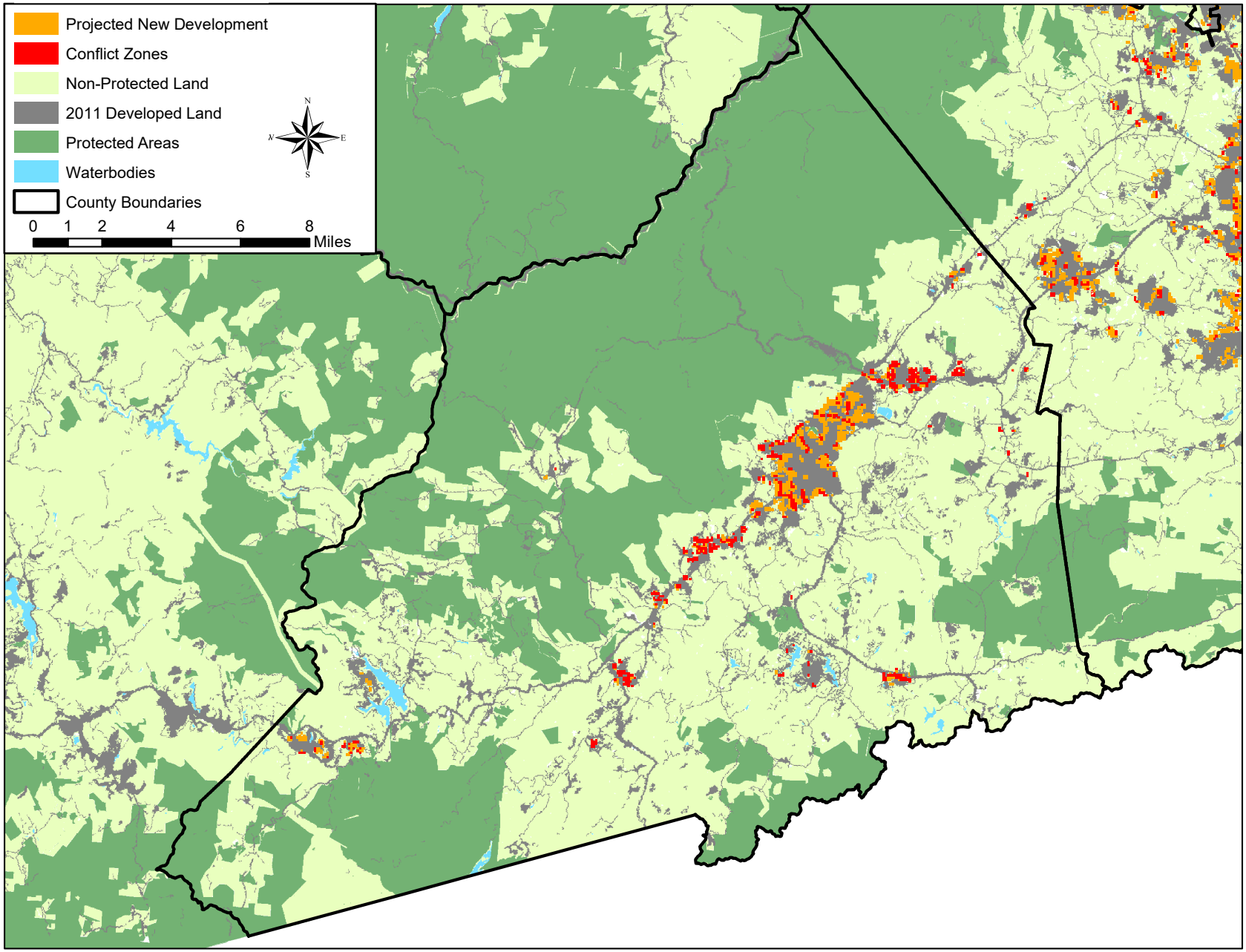

Figure 19. Infill Projected New Development and Conflict Zones in Transylvania County

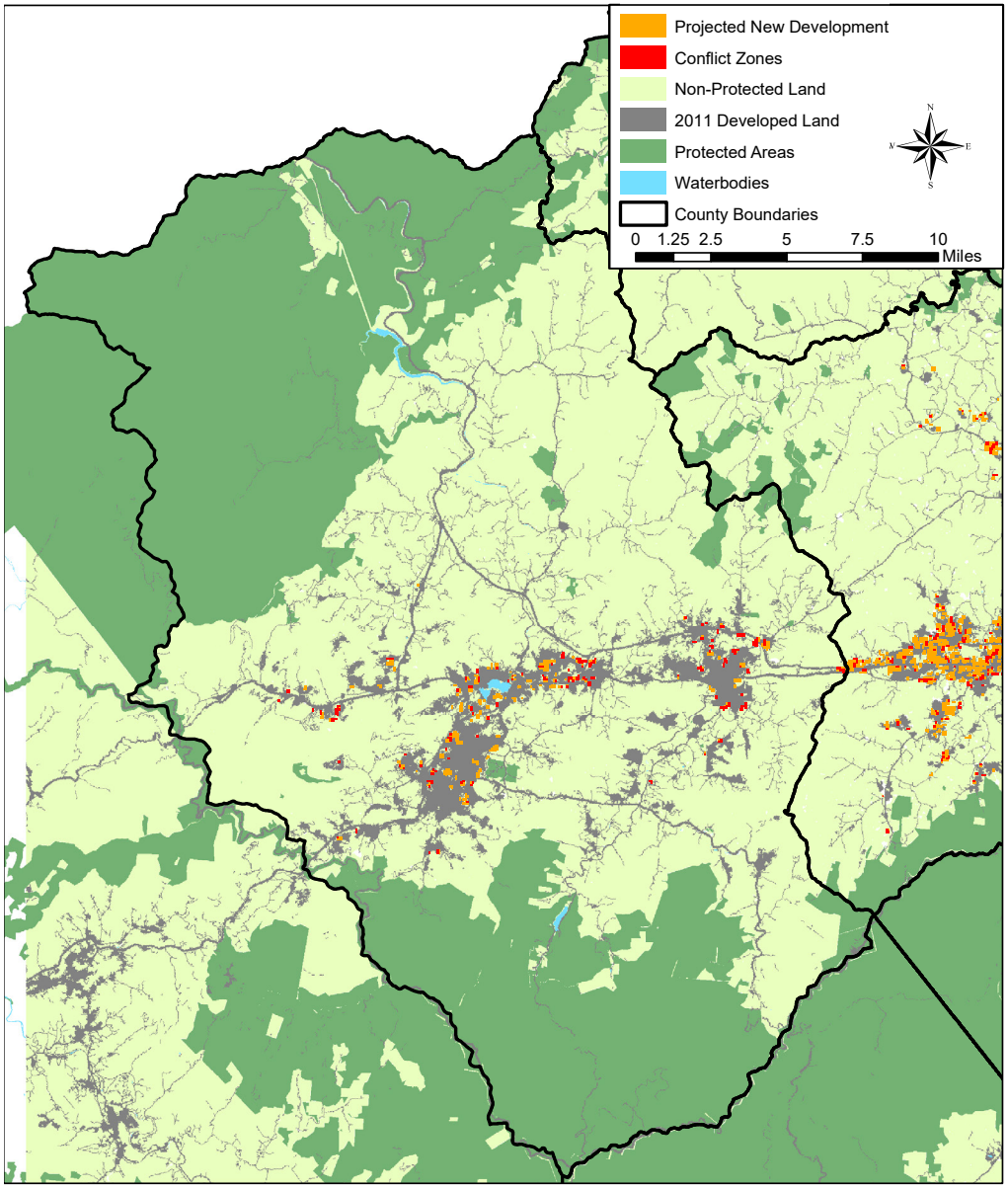

Figure 20. Infill Projected New Development and Conflict Zones in Haywood County

Madison County (Figure 18), Transylvania County (Figure 19), and Haywood County (Figure 20) all have conflict zones in areas where the forested area intersects or is close to the existing 2011 development. This is due to the high prevalence of protected areas as well as the low population density in these counties. The projected new development dispersion trends in these counties mimic those from business-as-usual scenario, except there are fewer conflict zones in the infill scenario. Prioritizing infill development will likely help preserve biodiversity in Asheville-Brevard CSA, but planners and city officials must still pay attention to where the best locations for infill development.

The Sprawl Scenario

The FUTURES model creates the sprawl scenario by maximizing the amount of spread allowed between patches (Figure 21). Effectively, the model does not generate patches next to existing development. In both Buncombe County and Henderson County, the projected new development appears evenly dispersed across the non-protected land of the counties. Haywood, Madison, and Transylvania County do not appear to have this dispersion because they have much lower projected populations through 2035.

The coverage area of the sprawl scenario is similar to the business-as-usual scenario. The main difference is the dispersal of the projected development away from 2011 developed land. In addition, this scenario contains the most projected development within 50 percent of a grid cell (195.33 km^2), but this is only around 3 km^2 more than the business-as-usual scenario (Table 7). This trend continues with the amount of projected development with a majority grid cell percentage for both Buncombe County (118.90 km^2) and Henderson County (52.85 km^2).

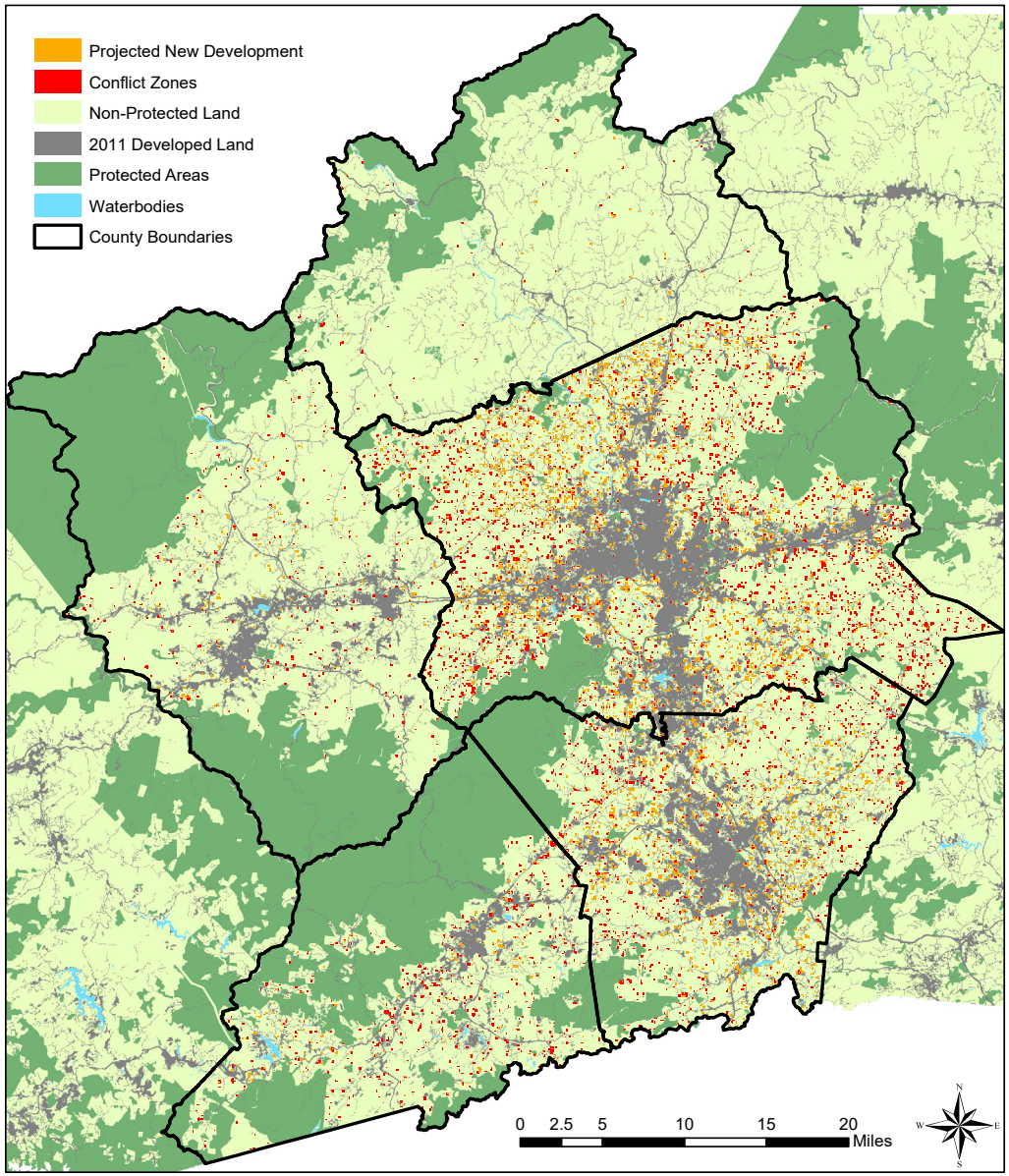

Figure 21. Sprawl Projected New Development and Conflict Zones in the Asheville-Brevard CSA

As seen in Table 8, the sprawl scenario (49.98 km²) has a larger amount of projected development intersecting with high conservation value land than the business-as-usual scenario. Figures 22-26 present the sprawl scenario large-scale maps for each county.

% of New Development in Grid Cell	Buncombe	Haywood	Henderson	Madison	Transylvania	Total Area
0.00	1308.86	822.41	779.00	927.01	501.19	**4318.31**
20.00	0.01	--	--	--	--	**0.01**
25.00	0.07	--	0.05	0.01	0.01	**0.13**
33.33	0.93	0.10	0.50	0.03	0.15	**1.72**
40.00	--	--	0.00	--	--	**0.00**
50.00	114.75	11.02	51.38	2.84	16.26	**195.33**
66.67	3.56	0.05	1.18	--	0.30	**5.07**
75.00	0.05	--	0.02	--	--	**0.07**
100.00	0.45	0.03	0.27	0.06	0.08	**0.90**
Total	**1428.68**	**833.60**	**832.40**	**929.94**	**517.98**	4521.54

Table 7. Area of Projected New Development in the Sprawl Scenario (in km²)[1]

[1]This table includes the projected new development outside and within conflict zones

County	Km²	% of Projected New Development	% of Non-protected Land
Buncombe	29.14	24.32%	2.04%
Haywood	3.55	31.72%	0.43%
Henderson	10.38	19.44%	1.25%
Madison	0.78	26.62%	0.08%
Transylvania	6.11	36.39%	1.18%
Total	**49.98**	**24.59%**	**1.11%**

Table 8. Area of Conflict Zones in the Sprawl Scenario

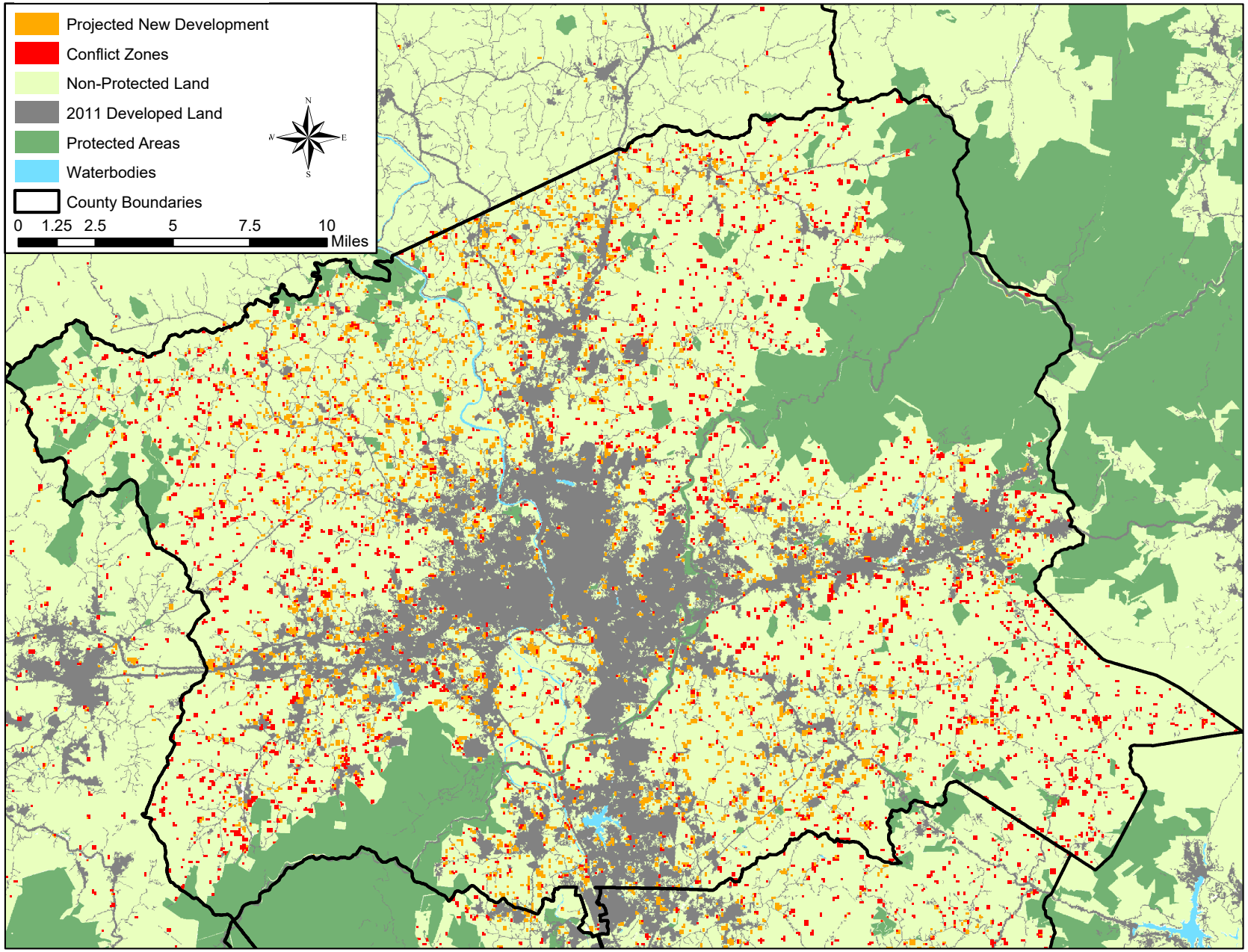

Figure 22. Sprawl Projected New Development and Conflict Zones in Buncombe County

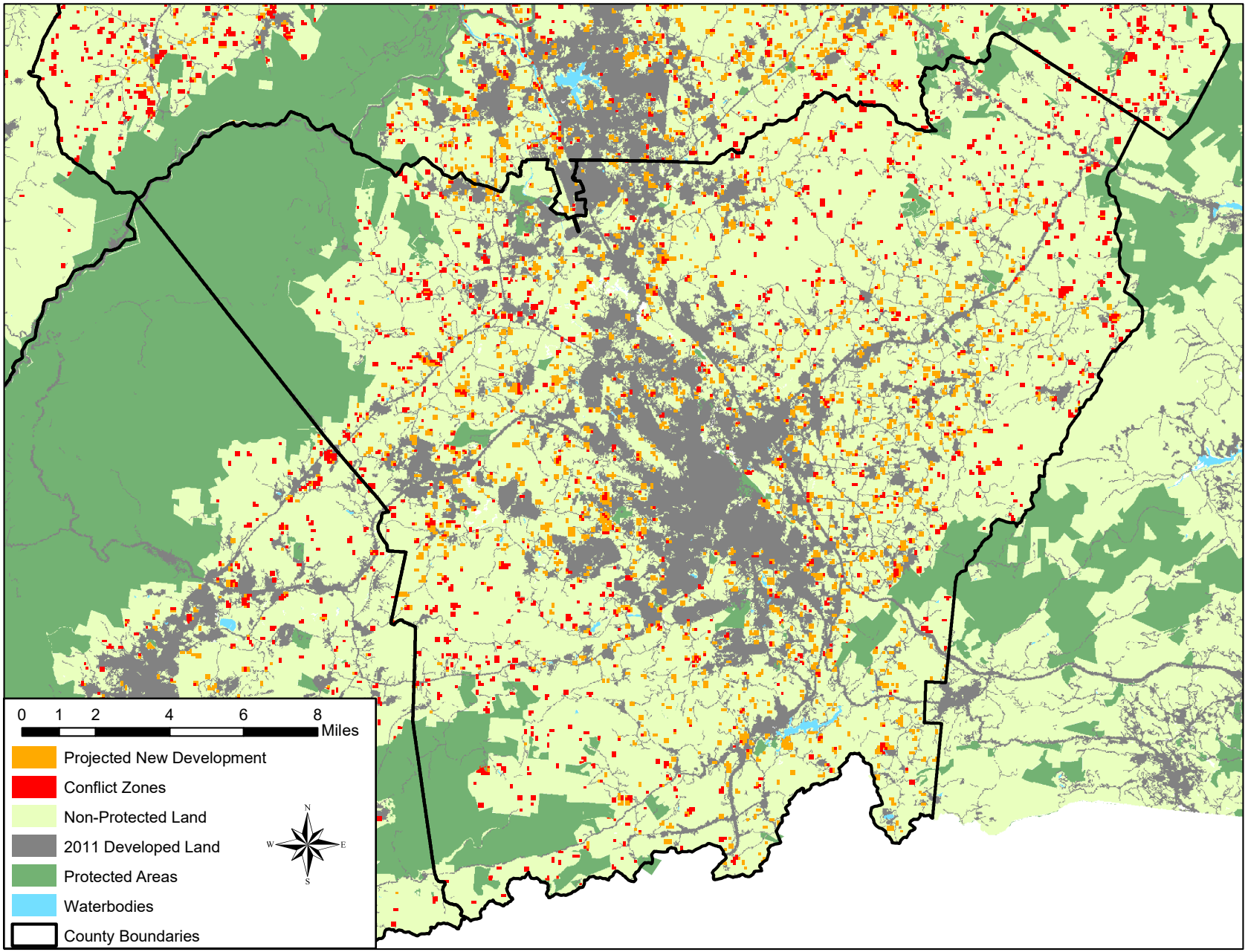

Figure 23. Sprawl Projected New Development and Conflict Zones in Henderson County

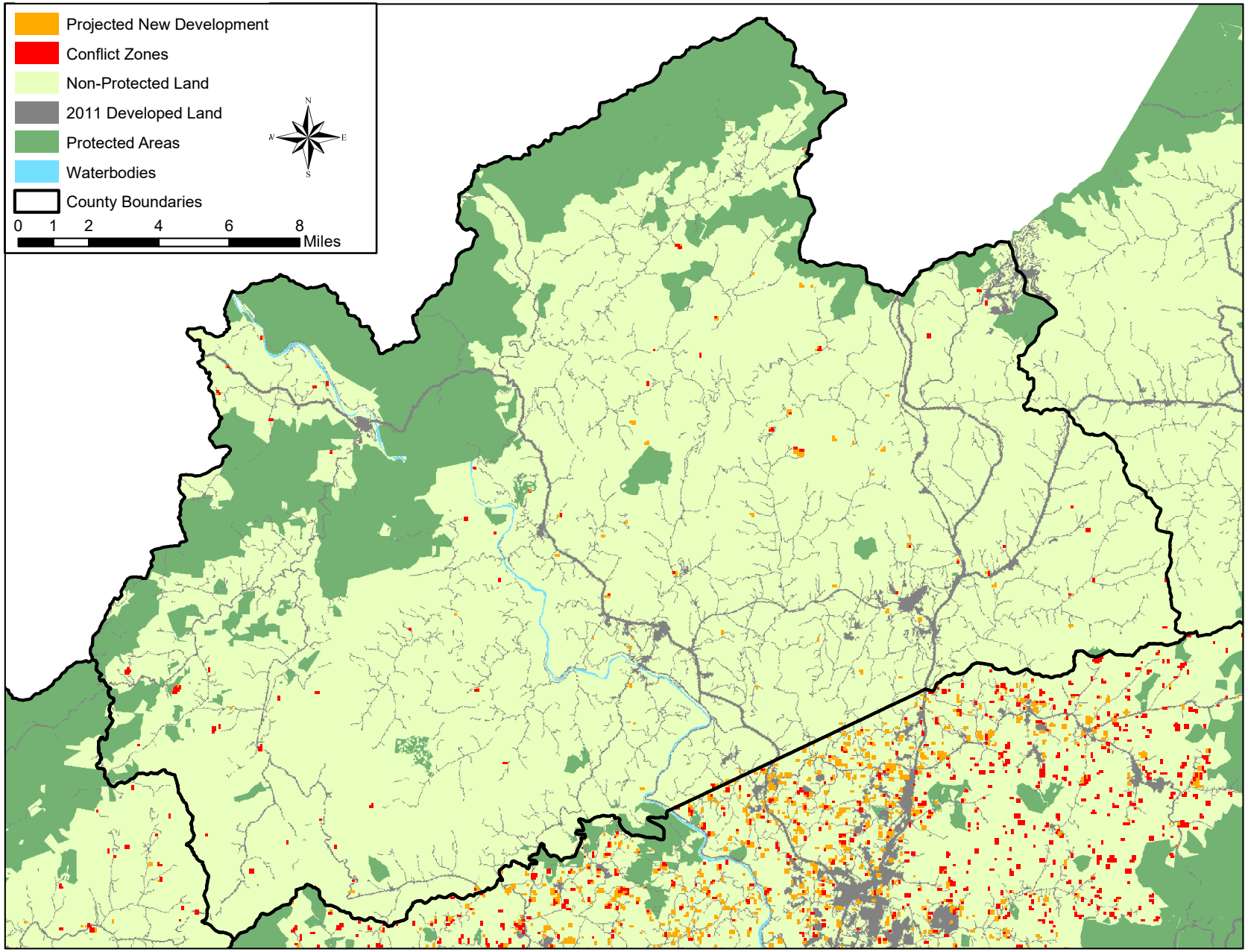

Figure 24. Sprawl Projected New Development and Conflict Zones in Madison County

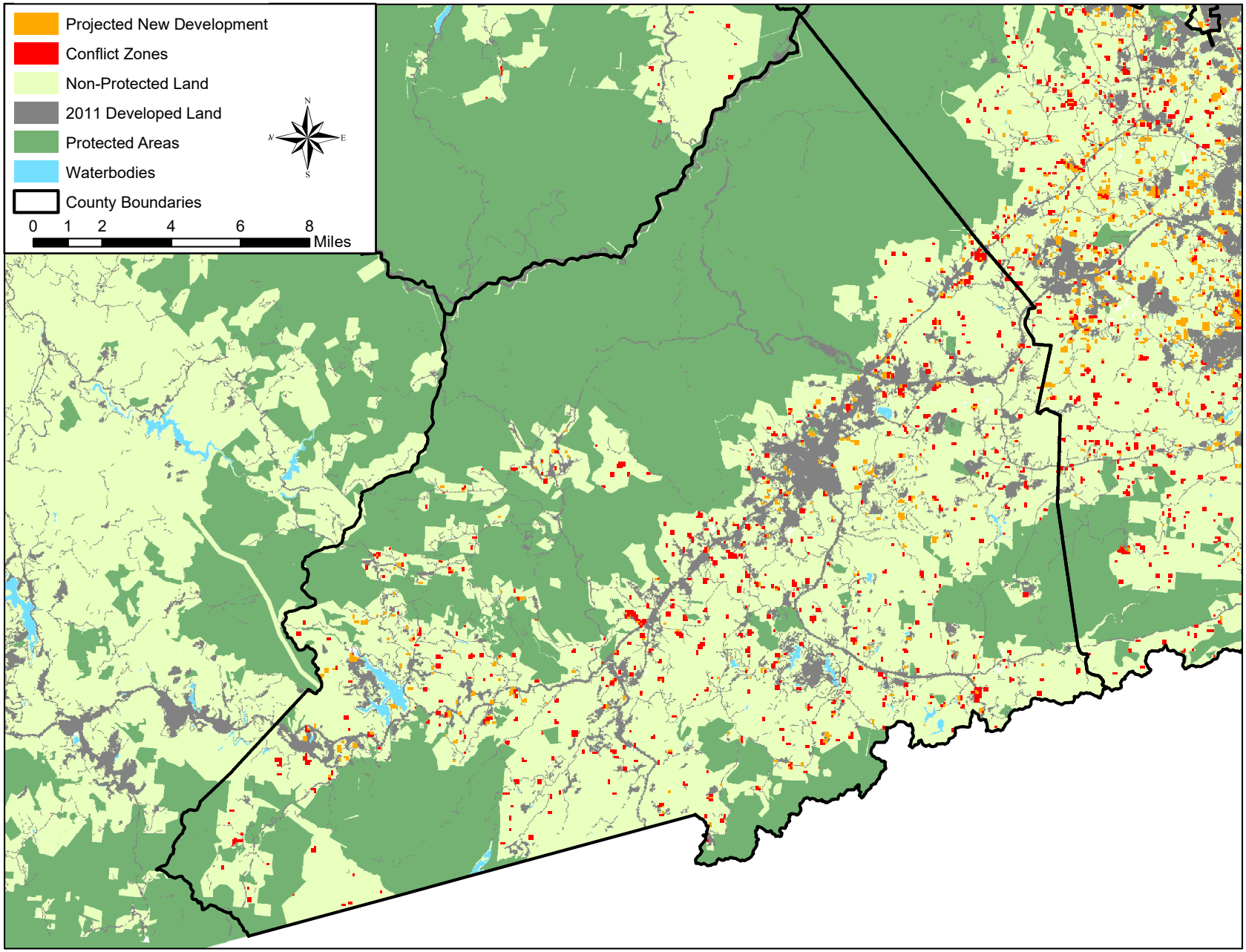

Figure 25. Sprawl Projected New Development and Conflict Zones in Transylvania County

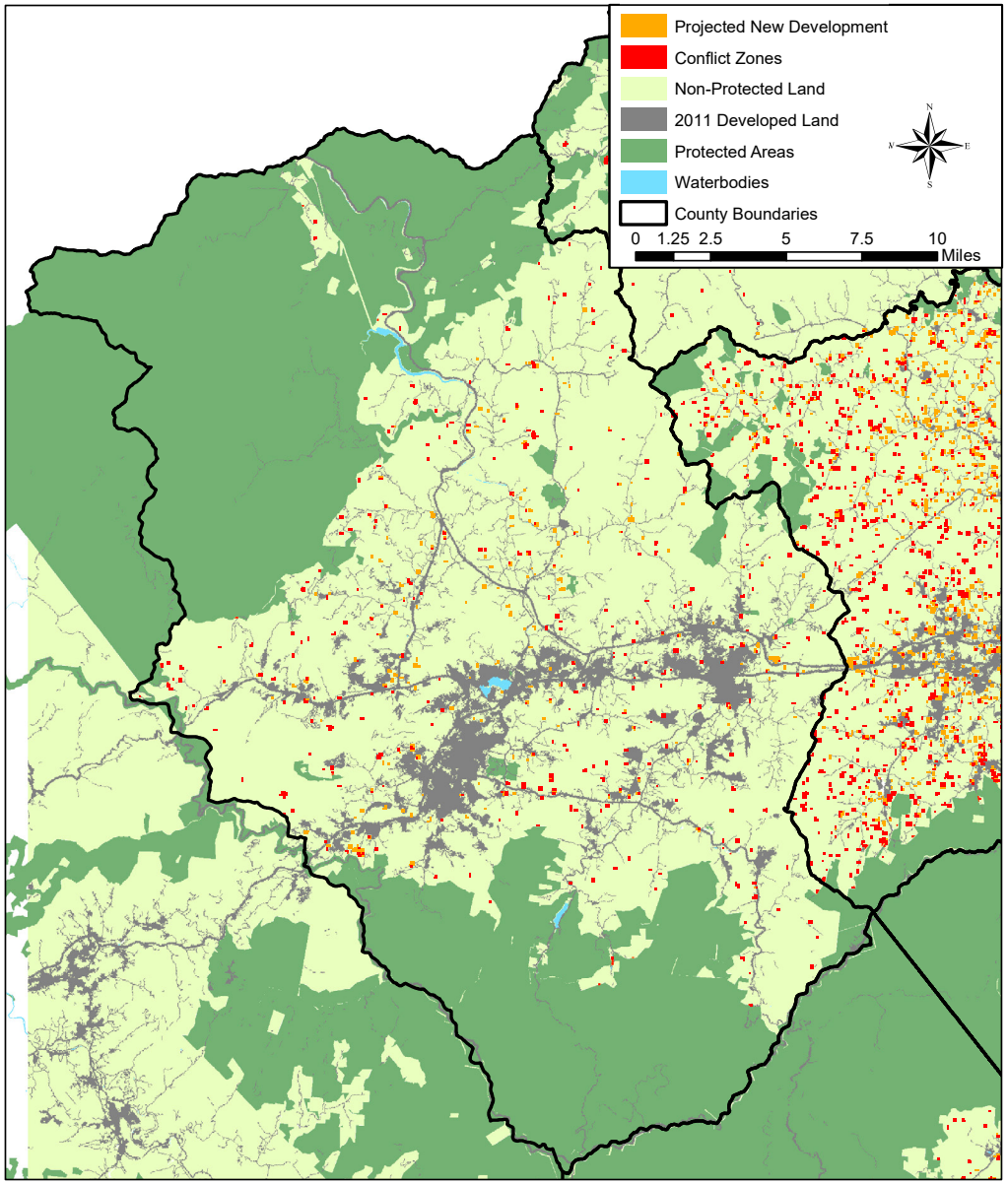

Figure 26. Sprawl Projected New Development and Conflict Zones in Haywood County

In Buncombe County (Figure 22) and Henderson County (Figure 23), the sprawl scenario displays clusters of conflict zones close to the national and state forests. In Buncombe, the conflict zones are near Pisgah National forest in both the northeast and southwest of the county. In Henderson, the conflict zones appear on the northeast, northwest, and southeast corners of the county. In general, it seems that the further away from the spines of the city and the major roads, the more likely that projected development intersects with highly sensitive land. This scenario depicts that conflict zones will cover 2.04 percent of non-protected land In Buncombe and 1.25 percent in Henderson. Planners and local officials must pay attention to the larger patches than would occur in more compact development.

Madison County (Figure 24) is interesting because the absolute amount of conflict zones within the sprawl scenario (0.78 km^2) is less than the business-as-usual scenario (1.86 km^2). However, the conflict zones make up more than 25 percent of the projected new development. This effect likely occurred because the other scenarios development near Hot Springs and Wolf Ridge Ski Resort, which protected land surrounds both and increases the likelihood of a conflict zone.

Extreme sprawl development would hurt Transylvania County because it would be difficult to prevent development from occurring in conflict zones. Within the scenario, conflict zones are relatively close to existing 2011 development compared to the other counties (Figure 25). This is probably due to the large amount of protected land that constrains where new development can occur. The conflict zones represent 36.39 percent of projected new development and 1.18 percent of total non-protected land within the county.

The sprawl scenario contains almost three times the amount of conflict zones (3.55 km^2) as the infill scenario in Haywood County. As with the other two development scenarios, the conflict zones occur in the heavily forested portions of the county (Figure 26). In particular, planners should monitor development in the eastern portion of the county for its impact on biodiversity, as this area contains a town, Canton, in the midst of high conservation value land, and development is projected to continue across the three scenarios.

Synthesis of the Results

This study demonstrates how three different development scenarios will intersect with land the North Carolina Biodiversity and Wildlife Habitat Assessment identified as having high conservation values. As expected, land closer to the protected areas of national forests, national parks, and state forests tends to have a higher conservation value. Streams and wetlands also tend to have higher conservation values, which leads to much of the conflict zones within the infill scenario.

The sprawl scenario contains the largest combined area of conflict zones followed by the business-as-usual scenario and then the infill scenario. In Buncombe County and Henderson County, local authorities and planners should strive for a development pattern similar to the infill and business-as-usual scenarios. In Haywood County, Madison County, and Transylvania County, planners should monitor the siting of new development as all three scenarios show highly sensitive land next to 2011 developed land. The following section will discuss recommendations.

RECOMMENDATIONS

The five counties and municipalities of the Asheville-Brevard CSA already implement many of the best practices for biological conservation. There is a substantial amount of protected land in the form of National Forests, National Parks, and NC State Forest. Communities have begun ecological restoration projects. Some developments are incorporating conservation zoning guidelines into their designs. However, conservation planning must remain at the forefront in future planning endeavors as the region continues to grow rapidly. In particular, local governments should begin to consider sustainable ecosystem services biodiversity conservation in the hearts of the urban areas.

This study hypothesized that conflict zones would be more prevalent closer to protected areas, which is partially true based on the results of the analysis. As expected, conflict zones are located near state forests and national parks, but they are also often located near streams and wetlands. The results of the analysis also indicate that pursuing infill development limits the combined area of the conflict zones. Therefore, the recommendations presented below focus on addressing these three findings: policies to promote infill development, policies to protect streams and wetlands, and policies for rural development.

Policies to Promote Infill Development

The three development scenarios used in the conflict zone analysis demonstrate that compact urban development will lead to a smaller impact on highly sensitive land, while the sprawl scenario increases the number of conflict zones. Therefore, local governments need to promote and incentivize infill development.

Infill development can "reduce development pressure on outlying areas, helping to safeguard lands that serve important ecological functions" (Office of Sustainable Communities 2014, i). In addition to promoting new construction near the centers of the municipalities, these policies should incorporate green infrastructure requirements. The green infrastructure requirements will help promote biodiversity and ecosystem services in the core of the towns.

In 2017, the Asheville City Council passed an ordinance to revise zoning codes to allow for small-scale residential infill development. In an effort to generate more middle housing (housing between single-family homes and large apartment complexes), the ordinance reduced the minimum lot width, incentivized housing unit variety through duplexes and accessory dwelling units, and allowed additional multifamily units for 1,000 square feet in excess of the minimum lot standards (Satvika 2017). This regulatory change not only helps address the city's need for housing and potentially limits sprawl, but it also allows the infill development to fit more closely with the character of the existing neighborhoods. Other municipalities in the area should follow Asheville's example and consider changing their zoning codes to support a wider variety of housing units on smaller lots.

Changing zoning regulations will be enough impetus for some developers to begin building closer to the city center, but other

developers may not be able to afford the often high price that smaller lots closer to the urban core command. Municipalities should consider subsidizing infrastructure costs for developments that do not contribute to sprawl. Perhaps local governments could lower impact fees for projects that are both built in areas surrounded by development and invest in green infrastructure or ecological restoration (Office of Sustainable Communities 2014).

Policies to Protect Streams and Wetlands

County and local governments should also look for opportunities for ecological restoration similar to the Park at Flat Rock. The Asheville-Brevard CSA contains at least 32 golf courses. If the sport continues to become less popular with younger generations as they age, local governments and neighborhoods may need to find alternative uses and many will look the success of the Park at Flat Rock as a guide. Golf courses are just one area where ecological restoration may occur. Apple orchards, summer camps, and office parks may all provide opportunities either to restore land to a similar environment that used to exist or to promote increased biodiversity through shared land uses.

Habitats and ecosystems around streams are severely altered by urban development. For example, development can straighten or cover a stream using engineered structures that destroy naturally occurring riparian vegetation. The impervious surfaces of urban environments increase the flow of water in the streams. These changes as well as chemicals from runoff cause the number of species within the habitat to plummet, which makes the ecosystem more vulnerable to other changes (Coles et al. 2012). Even with the Clean Water Act and additional regulations surrounding development near streams, local governments need to continue to place a strong emphasis on water protections. Given the complex nature of stream ecosystems as well as the myriad of effects urban development causes, management strategies need to be multifaceted in order to promote biodiversity. County and local governments should consider the following recommendations.

Establish a stream-setback ordinance that mitigates flood damage while maintaining natural resources, and maintain riparian buffers to promote biodiversity and filter stormwater runoff (Cappiella et al. 2012; Coles et al. 2012). These ordinances help protect streams that do not lie in recognized flood zones. At a minimum, local governments should strive for ordinances to be in line with the standards determined in the _The “NC Stormwater Requirements” section lists stream buffer widths that vary from 30 feet to 100 feet wide depending on the stream classification and the density of adjacent development (NC Department of Environmental Quality 2007). Streams within areas of higher density need wider wetbacks and buffers to provide additional filtration services.

Set impervious surface caps to mitigate amount of runoff entering streams rather than groundwater (Cappiella et al. 2012; Coles et al. 2012). Asheville currently has caps in its residential zones. As the density of the zones increases the impervious surface cap increases as well. Single-family residential zones have caps ranging from 20-50 percent impervious surface, and multi-family residential zones have caps ranging from 40-65 percent impervious (WNC Stormwater Partnership n.d.).

Incorporate low-impact development guidelines into zoning regulations (Cappiella et al. 2012; Coles et al. 2012). Many of the

regulations (Cappiella et al. 2012; Coles et al. 2012). Many of the zoning codes in the region already mention best practices, such as bioswales and permeable pavers, but incentives need to be provided to encourage developers to invest in this infrastructure. For example, the Midtown Alliance in Atlanta provides floor area ration density bonuses to developers who add public greenspace, affordable housing, and non-surface parking (Midtown Alliance 2013).

In addition to adding low-impact development guidelines into zoning regulations, local governments can invest in permeable pavers and green infrastructure such as bioswales in their own improvement projects. The City of Detroit Water and Sewerage Department collaborates with the Department of Public Works to install permeable surfaces, such as pervious concrete, and green infrastructure during scheduled road resurfacing (Water and Sewerage Department n.d.). Henderson County, specifically, should consider requiring pervious concrete or a different kind of smooth permeable pavement on future trails of the Greenway Master Plan adopted on April 1, 2019.

Regionally, authorities should draft and propose that the NC General Assembly pass an ordinance to add the French Broad River Basin to the NC Riparian Buffer Protection Program (NC Department of Environmental Quality n.d.). Given that the French Broad River Basin affects all of the counties of the Asheville-Brevard CSA, having an ordinance that discusses baseline riparian buffers for all of the local governments to abide by is a valuable way to protect almost all streams and rivers from future development.

Policies for Rural Development

While pursuing infill development is the primary recommendation based on the results of this study, it is unrealistic to expect sprawl will cease to exist in the Asheville-Brevard CSA. First, county governments must determine if there are additional areas outside of the current protected areas with large amounts of sensitive species. They should then tailor policies for the protection of these areas. Second, researchers should conduct studies and surveys to determine if the current protected areas provide a sufficient buffer for endangered species and sensitive populations. Once the tasks above are completed, local authorities can consider implementing the following recommendations: create conservation buffers around sensitive habitats and draft conservation zoning codes.

Conservation buffers are similar to riparian buffers, but they promote biodiversity and protect species in the core from encroaching development. If possible, buffers should be continuous around the perimeter of the defined habitat. They should be an appropriate width (around 300 feet up to 1,300 feet) based on the sensitivity of the species of concern, the habitat, and the landscape. Landscape-scale planning can help planners determine potential connections between protected areas, sensitive populations, and the conservation buffers that should be enhanced and preserved (The Nature Conservancy 2015).

As discussed in the literature review, conservation zoning and subdivision programs show promise and are beginning to be implemented in the Asheville-Brevard CSA. Local authorities should consider greatly expanding the reach of these conservation

subdivision policies by incorporating them in county zoning regulations. They should target these codes toward the edges of urban areas or new developments in heavily forested areas. In particular, Haywood County, Madison County, and Transylvania County would benefit from these regulations. Unlike Henderson County and Buncombe County, much of the land surrounding the current urban areas is forestland with a high conservation value rather than agriculture.

Conclusion

This study attempts to project where future development through 2035 will affect biodiversity in the Asheville-Brevard CSA. It adds to the current literature by analyzing a relatively small metropolitan area at a large scale in hopes for a more accurate depiction of where biodiversity conflict zones are likely to occur based on the development scenarios. The analysis determines that infill scenario will have the least conflict zones; however, planners must still create policies to ensure the protection of stream and wetland ecosystems as well as heavily forested rural areas.

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